Mid-Breton Land Bridge Marsh Creation & Terracing Project (BS-0032)

Coastal Wetland Planning, Protection, and Restoration Act PPL 27

Preliminary (95%) Design Report

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Executive Summary

The Mid-Breton Land Bridge Marsh Creation and Terracing Project is in Region 2 of the Breton Sound Basin in Plaquemines Parish, south of Lake Lery and west of Delacroix Island in the state of Louisiana, United States. The landfall of Hurricane Katrina in southeast Louisiana destroyed thousands of acres of marsh and other coastal habitats east of the Mississippi River. One of the areas most severely impacted was the Breton Sound Basin where an estimated 40.9 square miles of marsh were converted to open water. Without restoration, this region will continue to see the coalescence of water bodies such as Grand Lake, Lake Petit, and the surrounding marsh areas resulting in more direct connection between interior intermediate marshes and the open brackish Black Bay system and increased marsh loss due to wind induced erosion.

The goal of this project is to maintain/restore the land bridge between the Bayou Terre aux Boeufs and River aux Chenes ridges by restoring critical wetlands. It will also create or improve habitat for rare species, species of concern, and threatened and endangered species, including Least Bittern, Black Rail, Seaside Sparrow, and Saltwater Topminnow.

The project will create approximately 405 acres of intertidal marsh using sediment hydraulically dredged from Lake Lery. An additive alternate area will create an additional 109 acres totaling 514 acres. Existing canal spoil banks, emergent marsh, and segments of earthen containment dikes will be used to contain the dredged material in designated marsh creation areas. Earthen containment dikes will be degraded/gapped as necessary to reestablish hydrologic connectivity with adjacent wetlands. The project will also create approximately 22,000 LF of earthen terraces in strategic areas to reduce erosion due to wind induced waves.

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BA	Borrow Area
BS	Breton Sound
BUDM	Beneficial Use of Dredged Material
CME	Central Mine Equipment
CMFE	Constructed Marsh Fill Elevation
CPRA	Coastal Protection and Restoration Authority
CPT	Cone Penetration Test
CRMS	Coastwide Reference Monitoring System
CWPPRA	Coastal Wetlands Planning, Protection and Restoration Act
CY	Cubic Yard
DEM	Digital Elevation Model
DPC	Dredge Pipeline Corridor
EAC	Equipment Access Corridor
ECD	Earthen Containment Dike
ECDBA	Earthen Containment Dike Borrow Area
EP	Earthen Plug
ESA	Environmental Site Assessment
ESLR	Eustatic Sea Level Rise
ESRI	Environmental Systems Research Institute
FERC	Federal Energy Regulatory Commission
FGI	Fugro, Inc.
FT	Foot
GER	Geotechnical Engineering Report
GIWW	Gulf Intracoastal Waterway
GIS	Geographic Information System
GOM	Gulf of Mexico
HME	Healthy Marsh Elevation
HTRW	Hazardous, Toxic, and Radioactive Waste
LF	Linear Foot
LiDAR	Light Detection and Ranging
LNG	Liquefied Natural Gas
LS	Lump Sum
MC	Marsh Creation
MCA	Marsh Creation Area
MCBA	Marsh Creation Borrow Area
MCDG	Marsh Creation Design Guidelines
MHW	Mean High Water
MLW	Mean Low Water
MNA	Marsh Nourishment Area
MTL	Mean Tide Level
NAD83	North American Horizontal Datum of 1983
NAIP	National Agriculture Imagery Program
NAVD88	North American Vertical Datum of 1988
NGS	National Geodetic Survey
NMFS	National Marine Fisheries Services
NOAA	National Oceanic and Atmospheric Administration
NPMS	National Pipeline Mapping System
OPUS	Online Positioning User Service
PPL	Project Priority List
PSDDF	Primary Consolidation, Secondary Compression, and Desiccation of Dredged Fill
RPA	Registered Professional Archeologist
RSLR	Relative Sea Level Rise
RTK	Real-time Kinematic
SF	Square Foot

SHPO	State Historic Preservation Office
SLR	Sea Level Rise
SONRIS	Strategic Online Natural Resources Information System
SOP	Standard Operating Procedure
TA	Terrace Area
TIN	Triangulated Irregular Network
TY	Target Year
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Services
USGS	United States Geological Survey
WVA	Wetland Value Assessment

1.0 INTRODUCTION

1.1 Authority

The Louisiana Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) Task Force designated the Mid-Breton Land Bridge Marsh Creation and Terracing project (**Figure 1**) as part of the 27th Priority Project List (PPL27). The United States Fish and Wildlife Services (USFWS) was designated as the lead federal sponsor with funding approved through the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) of 1990 by the United States Congress and the Wetlands Conservation Trust Fund by the State of Louisiana. The Louisiana Coastal Protection and Restoration Authority (CPRA) is serving as the local sponsor and will provide engineering and design services.

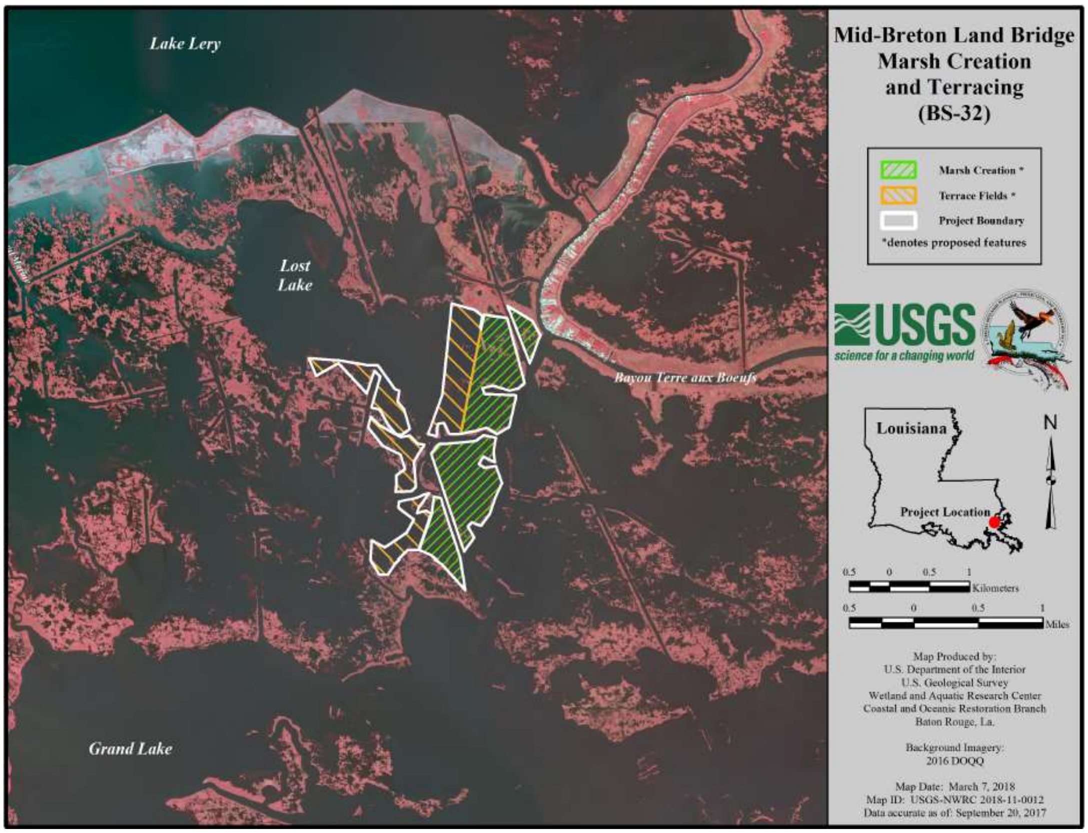

Figure 1: Phase 0 Project Area (CWPPRA 2018)

1.2 2017 Coastal Master Plan

The Mid-Breton Land Bridge Marsh Creation and Terracing project (BS-0032) in Plaquemines Parish is nested within a larger strategy to restore and preserve the Breton Land Bridge that separates inland water bodies from Breton Sound. This larger strategy is described in Louisiana's Comprehensive Master Plan for a Sustainable Coast (2017) as the East Bank Land Bridge Marsh Creation project (001.MC.104), which would create approximately 2,300 acres of marsh in the area between Lake Lery and Grand Lake (**Figure 2**). The land bridge will ultimately form a landscape feature to prevent the coalescence of water bodies into one large lake. The Mid-Breton Land Bridge Marsh Creation and Terracing project will be a strategic first component of the proposed land bridge and will ultimately contribute to a land bridge to deter coalescence of water bodies within the Breton Sound basin.

Figure 2: East Bank Land Bridge Marsh Creation Project (001.MC.104**)**

1.3 Project Consultant Team

CPRA utilizes an Indefinite Deliverable, Indefinite Quantity (IDIQ) process to procure consultant services to perform work and implement projects as outlined in the State's Master and Annual Plans.

Summary of consultants utilized for this project:

1) Bathymetric, geophysical, and magnetometers surveys.
   a) Primary contractor: **Fugro, Inc.**
      i) Subcontractor: **JMB Companies** (marine archaeology)
      ii) Subcontractor: **Juniper Unmanned** (drone-based geophysical surveying)
2) Geotechnical surveys and engineering
   a) Primary contractor: **Fugro, Inc**.
3) Cultural Resources Assessment
   a) Primary contractor: **Moffat & Nichol**
      i) Subcontractor: **Coastal Environments, Inc. (CEI)**
4) Phase I Environmental Site Assessment

    a) Primary contractor: **Gulf Engineers and Consultants, Inc. (GEC)**
5) Land Rights Research
    a) Primary contractor: **Independent Land Services (ILS)**

1.4 Physical Setting

The project area is located within the Breton Sound Basin, which is a remnant of the Mississippi River delta lobe, the abandoned St. Bernard Delta (**Figure 3**). The principal hydrologic features of the Breton Sound Basin include the Mississippi River and its natural levee ridges, the flood protection levee, abandoned delta distributaries, and the freshwater diversions at Caernarvon, White Ditch, Bohemia, and Bayou Lamoque. The barrier islands, which make up the Breton National Wildlife Refuge are far offshore and thus provide minimal protection.

A combination of human-induced and natural processes has contributed to land loss in the project area. These factors include saltwater intrusion, hydrologic modifications of the Breton Sound basin, oil and gas extraction and infrastructure, storm-driven erosion, subsidence, and sea-level rise. Since 1932, 47,036 acres (almost 17%) of the wetland area in the Breton Sound Basin has converted to open water. Without action, approximately one thousand (1,000) acres of marsh will continue to be lost each year. This loss amounts to approximately twenty thousand (20,000) acres during the next twenty (20) years. If no action is taken to restore and protect the remaining wetlands, it is projected that an additional 18% will be lost by the year 2040.

Figure 3: Project Vicinity Map

Land loss in the region was also exacerbated by the storm surge of Hurricane Katrina (2005), Hurricane Rita (2005), Hurricane Gustav (2008), and Hurricane Ike (2008) which caused inundation from surrounding intermediate to brackish waterbodies and wind-induced scour within the project area. The damaging effects of these three storms are shown in **Figures 4 and 5,** with a current satellite image in **Figure 6**.

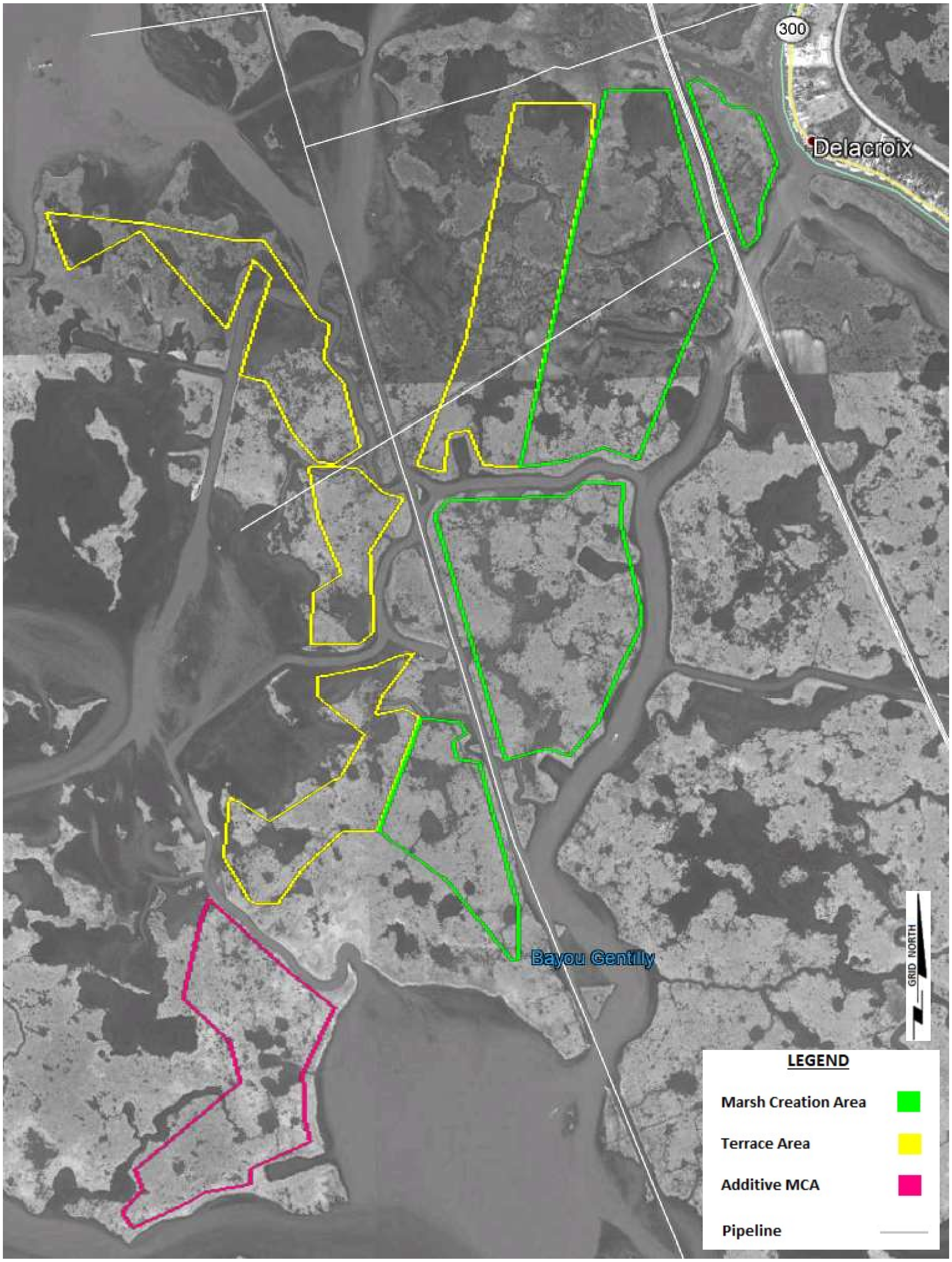

Figure 4: Pre-Hurricanes Katrina, Ike, Gustav, & Rita Satellite Imagery (2004)

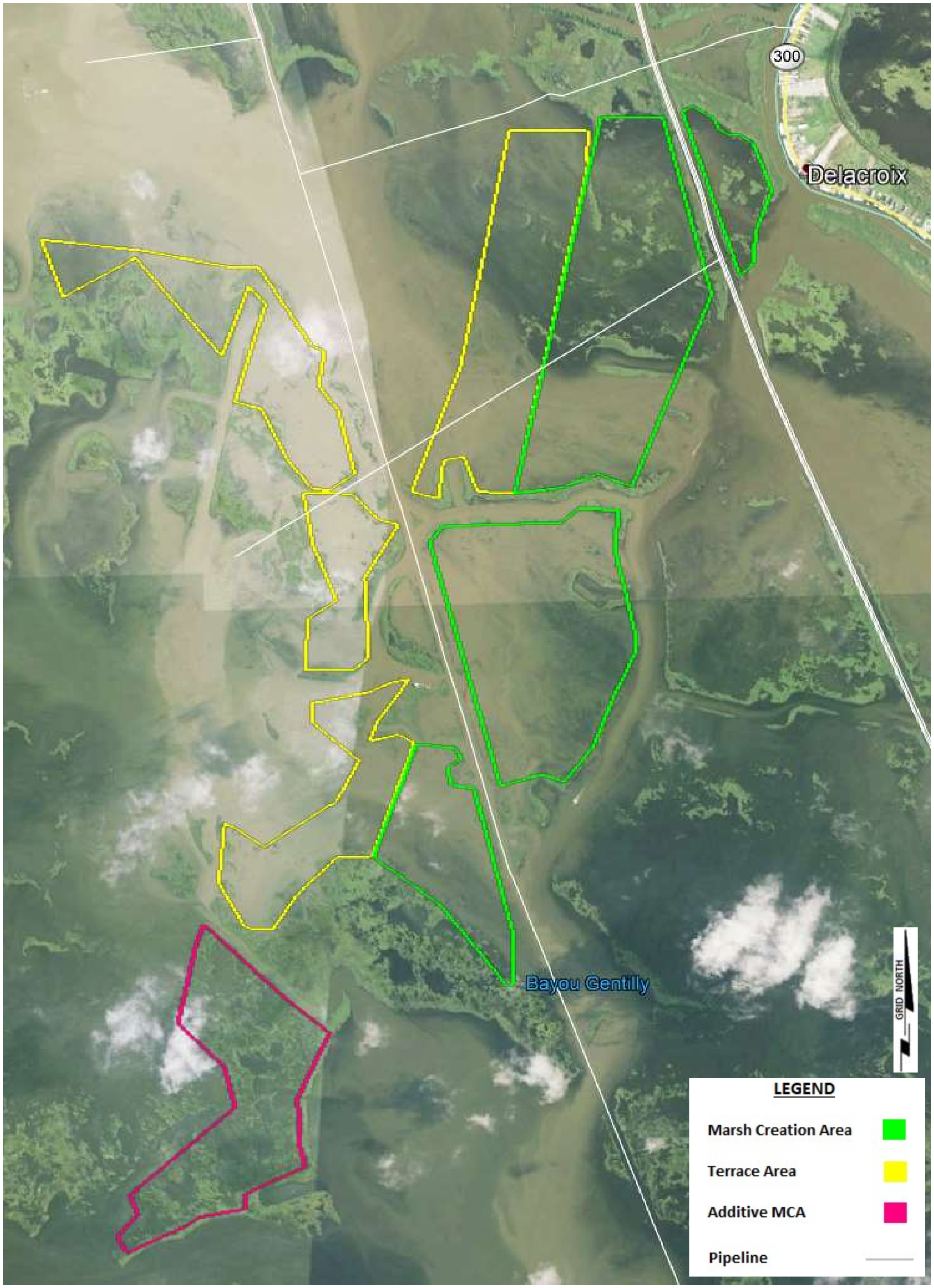

Figure 5: Post- Hurricanes Katrina, Ike, Gustav, & Rita Satellite Imagery (2010)

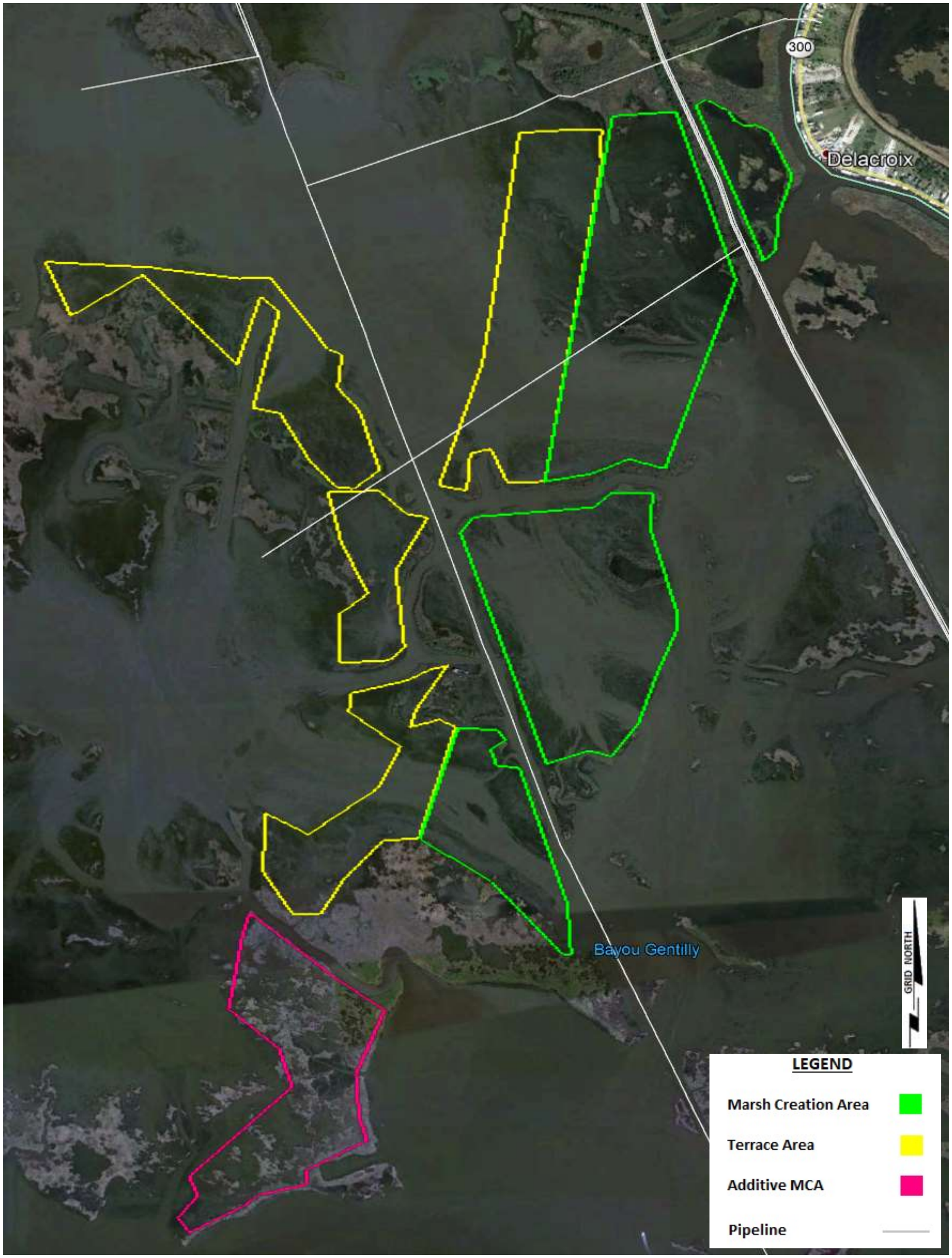

Figure 6: Current Marsh Creation and Terrace Area Satellite Imagery (2019)

1.5 Land Ownership

A land rights investigation was conducted by CPRA Land Rights Division following the CWPPRA SOP and implemented as per the CPRA's Marsh Creation Design Guidelines Version 1.0 (MCDG1.0) Section 3.4. This included a tax assessment report and title research.

Results of the title research indicate that the project area contains thirty-nine (39) privately owned parcels of land with approximately two hundred (200) undivided interest owners (**Figure 7**). These are primarily owned by individuals, but a small portion of the project areas is owned by Delacroix Corporation. The borrow area in Lake Lery is a state-owned water bottom.

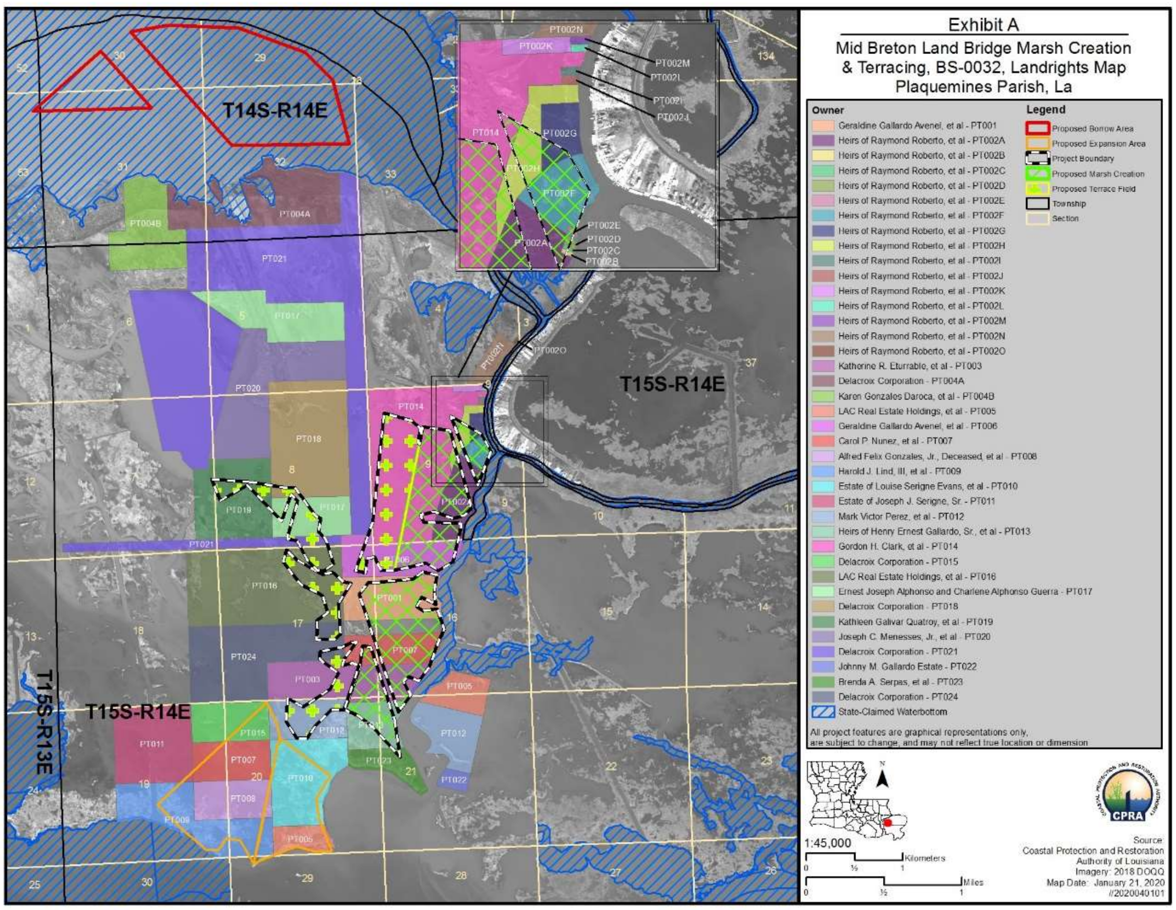

Figure 7: Land Rights Map (CPRA 2020)

1.6 Oyster Lease Assessment

No oyster leases have been identified near the marsh fill, terracing area, access and pipeline corridors, or borrow area.

2.0 CULTURAL RESOURCES

Two previously recorded prehistoric sites, 16PL21 and 16PL22, are located near the northernmost boundary of the marsh creation area, and one shell midden, 16PL23, exists on the shoreline of Lake Lery near the borrow site. The project team consulted with the Louisiana State Historic Preservation Office (SHPO) early in the project design process to request recommendations on how to avoid and protect these sites. USFWS initiated Section 106 consultation with tribes on June 28, 2018 and has remained in contact with tribal leaders throughout the preliminary design process. Tribal consultation is ongoing.

Cultural resources assessments were conducted separately for the borrow area and for the marsh creation and terracing areas. SHPO correspondence is provided in **Appendix A**.

2.1 Marsh and Terracing Areas

Phase I and II Cultural Resources Investigations were conducted by Coastal Environments, Inc. beginning in August 2019 under the direction of principal investigator Dr. Douglas C. Wells. A Phase I survey was conducted between August 26 and September 6, 2019 of the five marsh creation Areas of Potential Effects (APEs). Visual and probe/auger tests of the five areas yielded no archaeological sites or deposits indicative of prehistoric or historic activity. No further cultural resources work was deemed necessary for the marsh creation and terracing areas.

In addition to a Phase I survey of the marsh creation and terracing areas, SHPO recommended Phase II National Register of Historic Places (NRHP) testing be conducted at 16PL21 and 16PL22. The two sites were investigated between September 12 and October 3, 2019 by systematic shovel and auger testing, plus probing in submerged areas. Two test units were then excavated at each site.

Both 16PL21 and 16PL22 were recommended as eligible for listing on the NRHP under Criterion D (likely to yield information important to prehistory or history). SHPO recommended a fifty (50)-meter no-work buffer for the protection of site 16PL22.

2.2 Borrow Area

Sub-bottom seismic profile data, side scan sonar data, and marine magnetometer data were collected in the borrow area (**Figure 8**) as part of the project survey effort. Data were reviewed by Robert F. Westrick, Registered Professional Archaeologist, who provided an assessment addressing the prehistoric and historic resources within the borrow APE.

A review of the available research material indicated no standing historic structures and no NRHP-listed properties within the APE. Although there are no known archaeological sites within the Mid-Breton borrow area APE, one archaeological site, 16PL23, is of specific concern because it is located immediately south of the borrow area. A one-thousand (1,000)-foot buffer zone was created to avoid disturbance by activity related to the construction of the BS-0032 project. An area of shell, which is identified in the survey report as “oyster reef” (**Figure 8**), will also be avoided.

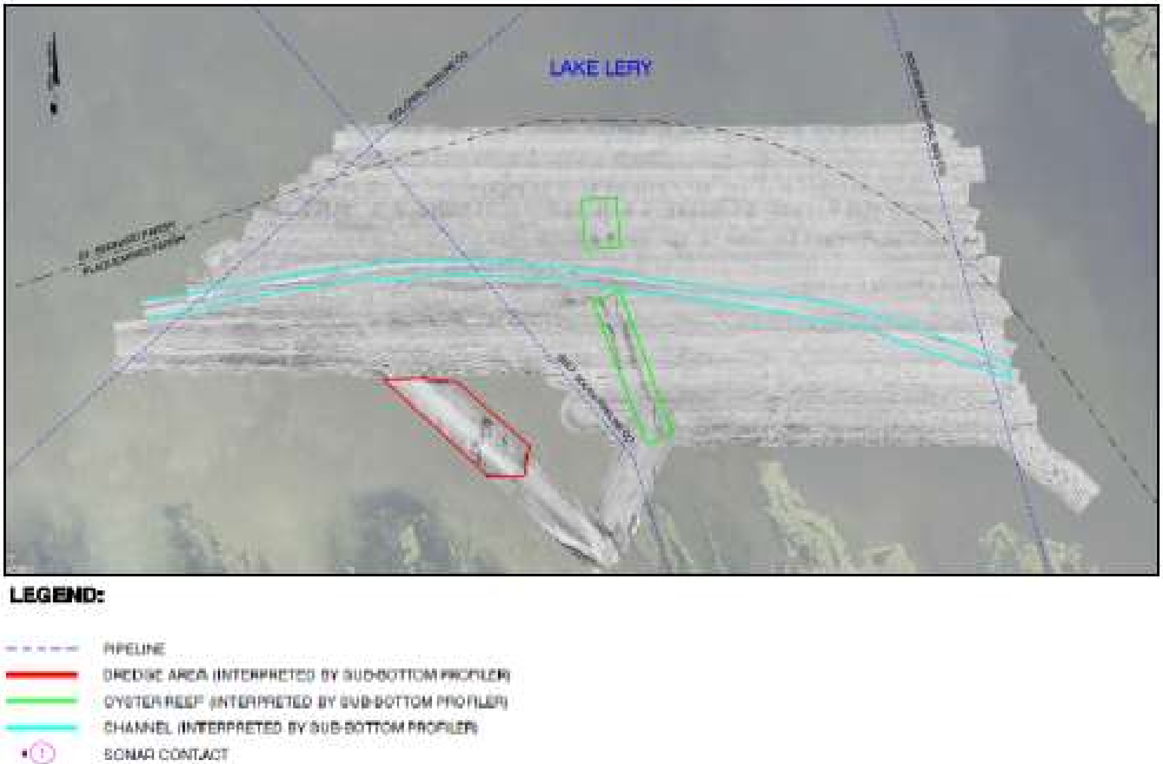

Figure 8: Interpretation of side scan sonar data. An area of shells indicated in green will be avoided.

3.0 HYDROLOGY

3.1 Sea Level Rise and Subsidence

To properly design the BS-0032 project and ensure it is built and performs according to the objectives of the 20-year project life, certain natural processes such as sea-level rise (SLR) and subsidence must be assessed. SLR refers to a global change in water level. The value associated with SLR is based on a global average rate of increase of water level that takes into account several variables including ocean heat uptake and thermal expansion, loss of glaciers and ice caps, and runoff from thawing permafrost. The CPRA Planning Division provided forecasted sea-level rise rates consistent with the 2017 Master Plan. These rates range from 0.5 to 1.98 meters of sea-level rise by year 2100 and are bracketed in various scenarios to account for uncertainty. The CPRA Planning Division recommends using the 1.0 meter (medium) scenario for the design of marsh creation projects (Demarco 2012). This accounts for nearly 6 inches of sea-level rise over the 20-year project design life.

Subsidence differs from SLR in that it is measured locally. Subsidence is defined as the rate of local vertical land movement. Natural causes of subsidence include plate tectonics and Holocene sediment compaction. Anthropogenic causes of subsidence include drilling and removal of subsurface fluids. Local subsidence rates in this region are approximately 5.8 mm per year (0.228 inches/yr) (Reed, Yuill 2016). This equates to a decrease in the project area mudline elevation of 4.56 inches over the 20-year project design life.

3.2 Tidal Conditions

The tidal datum is a standard elevation defined by a certain phase of the tide and issued to measure local water levels and establish design criteria. Typically, the primary objective for computing the tidal datum is to establish the optimal marsh elevation range that maximizes the duration that the restored marsh will be at intertidal elevation throughout the 20-year project life.

A tidal datum is referenced to a fixed-point known as a benchmark and is typically expressed in terms of mean high water (MHW), mean low water (MLW), and mean tidal levels (MTL) over the observed period. MHW is the average of all the high-water heights observed over one tidal epoch. MLW is the average of all the low water elevations observed over one tidal epoch. MTL is the mean of the MHW and MLW for that period.

The Coastwide Reference Monitoring System (CRMS) monitoring station CRMS0121 located at 29.6937923° N, - 89.8229752° W was selected as the control station because of its proximity to the project area (**Appendix C**). The five-year period of record used was November 19, 2014 to November 19, 2019 as per CPRA's *Marsh Creation Design Guidelines 1.0 (MCDG 1.0):* Appendix D: *Marsh Inundation Methodology*. The results of the tidal datum determination for the BS-0032 project area are as follows:

- MHW = +1.00 feet, NAVD88 (GEOID12A)

- MLW = +0.30 feet, NAVD88 (GEOID12A)
- MTL = +0.65 feet, NAVD88 (GEOID12A)

The mean high water (MHW) at CRMS0121 during the past five (5) years was +1.00 feet NAVD88, and the mean low water (MLW) was +0.30 feet NAVD88. This equates to a mean range in the tide of 0.70 feet.

3.3 Percent Inundation Determination

The vertical positioning of marsh platforms and the frequency with which the marsh floods strongly influence plant communities and marsh health (Visser 2003, Mitsch 1986). Historically, the tidal range between MHW and MLW has been the accepted range for healthy marsh. This approach only considers the tidal influences on the water levels, whereas, in many areas, non-tidal influences such as meteorological events, river discharges, and management regimes often have a large impact on the water levels found in that region. Percent inundation refers to the percentage of the year a certain elevation of land would be flooded. Therefore, using percent inundation rather than tidal range as a proxy for marsh health can give a more accurate representation of the water levels found in the area.

To determine percent inundation, the percentiles were calculated based on data gathered from the CRMS0121 station for a five-year period from November 19, 2014 to November 19, 2019. **Table 1** presents the percent inundation results with sea-level rise applied for the duration of the project life.

Salinity levels in the project area average 2 - 4 ppt; however, high salinity (> 20 ppt) peaks regularly occur for several weeks during the summer. The project area lies within a salinity gradient from intermediate to brackish, and given its function as a lad bridge, it is expected to form the boundary between intermediate and brackish once established. The project team determined that the marsh type that would ensure the long-term success of the BS-0032 marsh creation and terracing project is intermediate. Intermediate marshes are most productive when flooded between 10% and 90% of the time (Snedden 2012).

For design analysis of the marsh creation areas over the 20-year project life, the subsidence rate was applied to the marsh fill elevation, while the sea-level rise was applied to the tidal datum and the inundation range.

Table 1: Percent Inundation Elevations with ESLR

Percent Inundation Elevations with ESLR		
Percent Inundated	**TY0 Marsh Elevation @ 2022 (ft.)**	**TY20 Marsh Elevation @ 2042 (ft.)**
1%	2.60	3.10
10%	1.52	2.02
20%	1.20	1.70
30%	0.99	1.49
40%	0.82	1.32
50%	0.67	1.17
60%	0.52	1.02
65%	0.44	0.94
70%	0.35	0.85
80%	0.15	0.65
90%	-0.11	0.39

*Highlighted rows represent the optimal inundation range for intermediate marsh.

4.0 DATA COLLECTION

4.1 Topographic, Bathymetric, and Magnetometer Surveys

The design surveying was performed from March to August 2019 by Fugro, Inc. (**Appendix D**). Fugro completed the topographic, bathymetric, magnetometer, geophysical surveys and probing investigation in the marsh creation and terracing areas in May 2019 and completed the bathymetric, magnetometer, and geophysical surveys of Lake Lery borrow area in April 2019. Juniper Unmanned, Inc. (Juniper), a subcontractor to Fugro, performed low-altitude aeromagnetic surveys in May 2019 in the marsh creation and terracing areas as well as various locations along known pipelines in Lake Lery to confirm accuracy.

Survey data collected for design and analysis include the following:

- Bathymetric, magnetometer, and geophysical surveys of Lake Lery borrow area.
- Topographic, bathymetric, and magnetometer/aerial magnetometer surveys of the Marsh Creation Area and Dredge Pipeline Corridor.

4.1.1 Survey Datum

The horizontal datum is NAD1983 and vertical datum is NAVD 1988 GEOID 12A.

4.1.2 Horizontal and Vertical Control

The horizontal and vertical controls for the topographic survey were constrained to monument BS32 SM 01, which was newly installed on September 16, 2019. The field survey was accomplished utilizing real-time kinematic (RTK) surveying procedures and checked using the National Geodetic Survey (NGS) Online Positioning User Services (OPUS). The data sheet for the survey monument is provided in **Appendix C**.

4.1.3 Marsh Creation and Terracing Surveys

Fugro began surveying the marsh creation and terracing area on March 27, 2018. Survey transects were surveyed in a grid approximately every five-hundred (500) feet. Transects were taken across open water areas, broken marsh, and across pipeline canals. Position, elevation, and water depths were recorded every twenty-five (25) feet along each transect or where elevation changes were greater than one-half (0.5) feet.

Topographic and bathymetric survey methods were used as applicable to obtain all transects and were consistent with CPRA's *Marsh Creation Design Guidelines Version 1.0 (MCDG 1.0):* Appendix A: *A Contractor's Guide to the Standards of Practice*. The topographic portions were merged with the bathymetric portions at the land/water interface and were separated by no more than fifty (50) feet. Side shots were taken as necessary to pick up variations in topographic features (highs and lows) such as trenasses, meandering channels, broken marsh areas, or any other existing infrastructure such as pipelines, wellheads, duck blinds, and warning signs, which may affect project design implementation. A fixed-height aluminum rod, eight (8) feet or ten (10) feet in length, with a six (6)-inch diameter metal plate as the base of the rod was used to prevent the rod from sinking when topographic data was collected.

4.1.4 Magnetometer Survey and Pipeline Probing Investigation

A magnetometer survey was also taken along all transects, as shown in **Appendix D** to locate any pipelines or other infrastructure in the fill area. The aerial magnetometer survey detected two hundred fifty-two (252) magnetic anomalies in the marsh creation and terracing areas. These anomalies ranged in amplitude from two (2) to five hundred fifty-five (555) gamma, and in duration from ninety-one (91) to three thousand eight hundred four (3,804) feet. Of these anomalies, two hundred thirty-six (236) were determined to be possibly associated with pipelines using conventional probing techniques. These magnetic contacts correlated to seven pipelines, the Southern Natural Gas Pipelines, Gulf South Pipelines, and LA Land & Exploration Co. Fugro also identified several exposed pipes in the survey area. These exposed flow lines appeared to be near the border edges of the project area footprint. A map and table summary of the probing survey is shown below in **Figure 9** and **Table 2**.

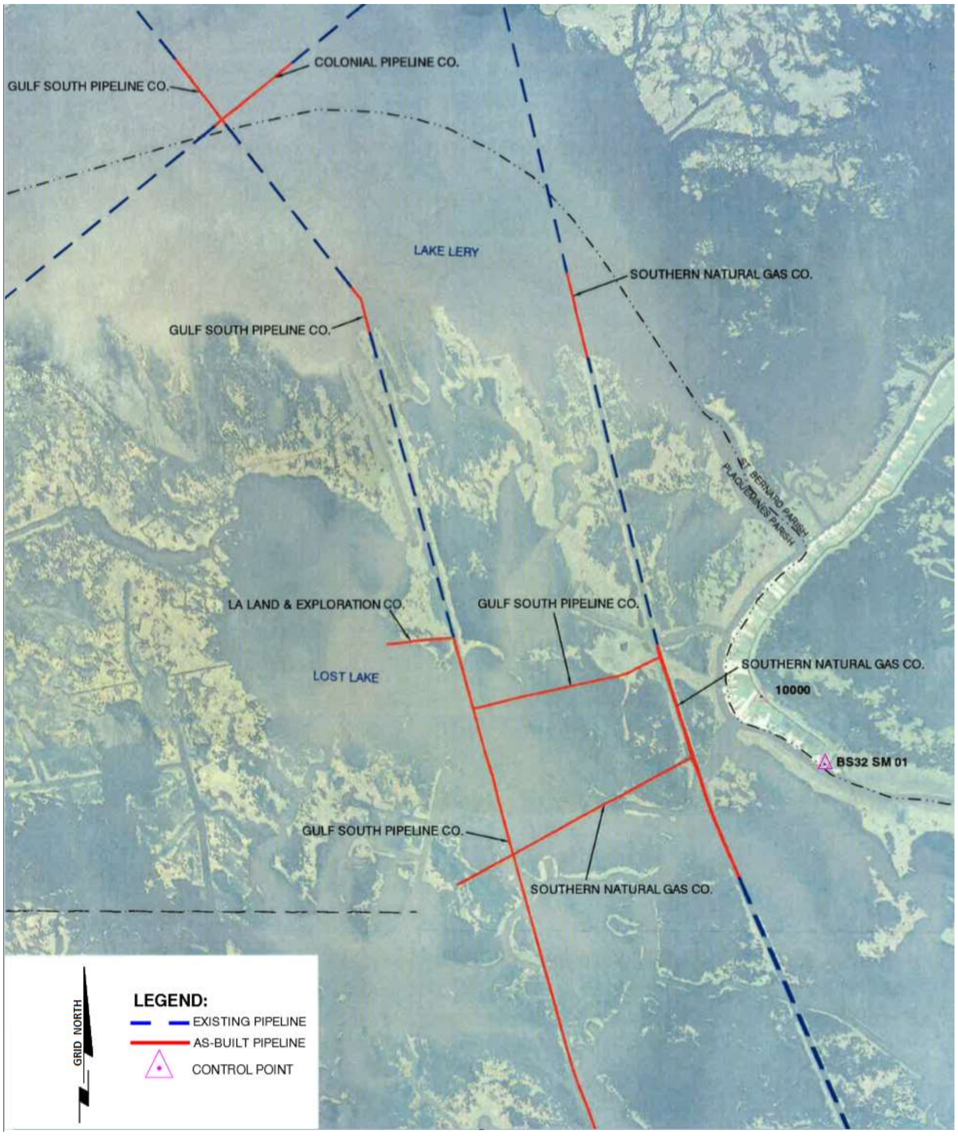

Figure 9: Probing Investigation (Fugro, Inc. 2019)

Fugro identified two unmarked pipelines that were not previously identified through observed signage, the National Pipeline Mapping System (NPMS) website, or the Strategic Online Resources Information System (SONRIS) database. One of the Southern Natural Gas pipelines crosses through MCA-2. The current design includes constructing a dike across this pipeline; however, CPRA is seeking additional information from the pipeline owner to determine if the pipeline should be avoided. The second previously unidentified pipeline is owned by LA Land & Exploration. This pipeline is in a location which will require the dredge pipeline to float over it, but it is not in the MCA/TA. CPRA Land Rights Division has contacted the pipeline companies to request the status of each pipeline.

A summary of the information collected on these pipelines is shown below in **Table 2.**

Table 2: Pipelines in the Marsh Creation & Terrace Area

Pipeline Ownership/Operator	Depth of Cover (ft.)	Size (in.)	Product
Southern Natural Gas (Profile C)	0-9.5	20	Gas
Southern Natural Gas (Profile E)	3.5-6	26	Gas
Southern Natural Gas (Profile F)	4.5-11	20	Liquid
Gulf South (Profile A)	0-6.5	unknown	Gas
Gulf South (Profile D)	0.5-5.3	unknown	Gas
Unknown (Profile J)	1-8.8	unknown	unknown

4.1.5 Lake Lery Borrow Area

Survey transects of the proposed borrow area were taken every one hundred (100) feet from west to east. Position, elevation, and water depth were recorded every fifty (50) feet along each transect or where elevation changes were greater than one-half (0.5) feet. The water bottom elevation data obtained from these surveys were used for determining borrow volumes. The water bottom elevation ranges between minus-six (-6) to minus-seven (-7) feet NAVD88. Bathymetric survey methods consistent with the CPRA *MCDG 1.0*: Appendix A (*A Contractor's Guide to the Standards of Practice*) were used to obtain all transects.

In addition to a bathymetric survey, magnetometer and sub-bottom seismic surveys were performed along the same transects as the bathymetric survey. One hundred sixty-four (164) magnetic anomalies were detected in the borrow area. The G-882 marine magnetometer detected one hundred forty-eight (148) anomalies identified as pipelines and four hundred thirty-three (433) unidentified magnetic anomalies that could not be correlated to known features within borrow area. The unidentified magnetic anomalies displayed amplitudes ranging from ten (10) to seven thousand two hundred forty-five (7,245) gammas, and durations ranging between six (6) to seven hundred sixty-two (762) feet. The few magnetic anomalies are associated with sonar contacts were interpreted as potential crab traps. Most of the unidentified magnetic anomalies recorded were interpreted as small, buried ferrous debris. None of the unidentified magnetic anomalies display characteristics that would indicate the presence of historical shipwrecks or other significant submerged archaeological resources. Therefore, no magnetic anomalies were recommended for archaeological avoidance. However, an area of suspected of shell material indicated on survey maps as "oyster reef" (**Figure 8**, **Appendix D**) will be avoided by a one thousand (1,000)-foot buffer zone. There are no oyster leases in Lake Lery, therefore the shell material was not further investigated.

4.1.6 Dredge Pipeline Corridor Alignment Surveys

Marsh fill will be delivered hydraulically by floating pipeline from the borrow area to the fill area. A magnetometer survey was performed along the potential dredge pipeline alignments, and specifically where the dredge pipeline corridor will cross, to check for any anomalies. These pipelines include LA Land and Exploration Co., Gulf South Pipeline Co., and Southern Natural Gas Pipeline Co. Results are provided in **Appendix D,** and a visualization of the layout is displayed in **Section 5.7** of this report.

4.1.7 Average Marsh Elevation Survey

Elevations from five healthy marsh sites in the existing marsh were surveyed to determine an average existing marsh platform elevation. Marsh elevation survey locations are shown in **Figure 10**. A total of one hundred forty-one (141) topographic points collected at natural ground were collected across the five sites on April 22, 2019. A minimum of twenty (20) elevations, each one separated by twenty (20) to forty (40) feet, were collected at each site.

Figure 10: Marsh Elevation Survey Locations

The results from the marsh elevation survey are shown below in **Table 3**.

Table 3: Average Marsh Elevation Results

Method	# Points	Elevation (ft, NAVD88)
Healthy Marsh Survey	141	0.85

According to the survey, the average marsh elevations near the project area is approximately 0.85 ft., NAVD88. At this elevation, the marsh surface is estimated to be inundated between thirty (30) to forty (40) percent of the time.

4.2 Geotechnical Investigation

Fugro was tasked to explore and evaluate the subsurface soil conditions and guide the geotechnical aspects of the design and construction of BS-0032. Field explorations began on October 14, 2019 and lasted until October 17, 2019. Fugro was tasked with the following data collection efforts:

- Collect eight (8) borings to a depth of twenty (20) feet in Lake Lery.
- Collect seven (7) soil borings in the marsh creation and terrace areas.
- Perform twenty-five (25) Cone Penetrometer Test (CPT) soundings along the proposed containment dike and in terrace locations.
- Perform laboratory classification and strength testing to determine soil characteristics.
- Perform three composite low-pressure consolidation tests.
- Perform one column settling test on the selected composite sample.

In addition to data collection, Fugro was also tasked to perform the following geotechnical analyses:

- Slope stability analysis of the proposed ECD and Terraces.
- Total settlement estimates of the proposed ECDs, marsh creation areas, and terraces.

Links to the geotechnical data collection and data analysis reports can be found in **Appendix E** and **F**, respectively.

4.2.1 Existing Geotechnical Data Review

Before conducting the field subsurface investigation, a search of any historical data on the area was conducted. This included looking at prior subsurface investigations that occurred in the area as well as reviewing historical geological maps. The review found a geotechnical engineering report produced by GeoEngineers for the Lake Lery Marsh Creation Project (BS-0016). Soil boring logs and geotechnical analysis for the BS-0016 project were reviewed by CPRA.

The geotechnical subsurface investigation and geotechnical engineering analysis for BS-0032 was conducted by Fugro with guidance provided by the CPRA Project Engineer and as per the *MCDG1.0, Appendix B, Geotechnical Standards-Draft*.

4.2.2 MCA and Terracing Area Geotechnical Subsurface Investigation

Seven (7) subsurface borings were taken in the MCA by Fugro to depths ranging from approximately thirty (30) to thirty-two (32) feet below the existing mudline. The soil borings were performed using an airboat with a mounted drilling rig. The mudline ranged from elevations of -2.06 feet to -0.5 feet NAVD88.

Samples were collected continuously with a piston sampler in Shelby tubes in the upper twenty (20) feet of the soil and on five (5)-foot centers thereafter to boring completion depths. All samples were then classified, stored, and transported to the laboratory. Shelby tube samples were tested for shear strength using a miniature pocket vane and removed from their tubes. Laboratory tests included soil compressive strength, moisture content, organic content, grain size analysis, specific gravity, consolidation with rebound, and Atterberg limits. A summary of the geotechnical investigation is shown in **Table 4**.

Subsurface soil conditions that were encountered from eight (8) boring locations in the borrow area consist primarily of clays with organic clay and peat layers present from the mudline to a depth of about twenty (20) feet. The terrace and MCA explorations consist primarily of clays with interbedded sand and silt layers of varying thickness from seven (7) borings that were collected. Near the surface, earth materials consist of organic clay and peat layers from the mudline to a depth between two (2) to six (6) feet. Medium to very stiff clay soils were encountered below depths of sixteen (16) to twenty (20) feet, with a few exceptions. Soil conditions were also evaluated in the marsh creation and terrace areas by performing twenty-five (25) CPTs using an airboat-mounted rig at depths ranging from eighteen (18) to thirty (30) feet below the existing mudline.

The approximate sampling locations are shown in **Figure 11,** and the boring logs and CPT data can be found in **Appendix E**.

Table 4: Optimized Subsurface Investigation Plan Soil Borings and CPT Locations

ID	Lat. (deg.)	Long. (deg.)	Mudline Elevation (ft. NAVD88)	Depth (ft.)	Type and Location
B-01	29° 47' 60"	-89° 48' 56"	-6.79	20	Boring - Lake Lery
B-02	29° 47' 54"	-89° 48' 39"	-6.18	20	Boring - Lake Lery
B-03	29° 47' 49"	-89° 49' 07"	-6.38	20	Boring - Lake Lery
B-04	29° 47' 41"	-89° 48' 47"	-6.97	20	Boring - Lake Lery
B-05	29° 47' 41"	-89° 48' 28"	-6.17	20	Boring - Lake Lery
B-06	29° 47' 29"	-89° 48' 58"	-5.61	20	Boring - Lake Lery
B-07	29° 47' 27"	-89° 48' 41"	-1.42	20	Boring - Lake Lery
B-08	29° 47' 27"	-89° 48' 24"	-6.18	20	Boring - Lake Lery
MC2-1	29° 45' 13"	-89° 48' 07"	-3.54	30	Boring - Fill Area
MC2-2	29° 45' 29"	-89°47' 49"	-2.06	30	Boring - Fill Area
MC3-9	29° 44' 43"	-89 °48' 07"	-2.41	30	Boring - Fill Area
MC4-3	29° 44' 20"	-89° 48' 28"	-2.82	30	Boring - Fill Area
MC5-6	29° 43' 46"	-89° 49' 01"	-3.09	30	Boring - Fill Area
T1-3	29° 45' 26"	-89° 48' 56"	-2.14	30	Boring - Fill Area
T3-1	29° 44' 43"	-89° 48' 36"	-2.19	32	Boring - Fill Area
MC1-1	29° 45' 35"	89° 47' 34"	-1.27	30.96	CPT - Fill Area
MC2-1-2	29° 45' 13"	89° 48' 07"	-3.18	29.98	CPT - Fill Area
MC2-2-2	29° 45' 29"	89° 47' 49"	-2.29	28.67	CPT - Fill Area
MC2-3	29° 45' 02"	89° 48' 10"	-1.27	30.24	CPT - Fill Area
MC2-4	29° 45' 16"	89° 47' 44"	-5.49	30.24	CPT - Fill Area
MC3-4	29° 44' 50"	89° 48' 23"	-1.88	30.18	CPT - Fill Area
MC3-7	29° 44' 47"	89° 47' 54"	-1.62	31.62	CPT - Fill Area
MC3-9-2	29° 44' 43"	89° 48' 08"	-2.34	30.9	CPT - Fill Area
MC3-11	29° 44' 31"	89° 48' 16"	-2.04	31.36	CPT - Fill Area
MC3-14	29° 44' 36"	89° 47' 55"	-3.24	30.44	CPT - Fill Area
MC3-20	29° 44' 25"	89° 48' 03"	-1.25	30.57	CPT - Fill Area
MC4-3-2	29° 44' 20"	89° 48' 28"	-3.08	30.77	CPT - Fill Area
MC4-11	29° 44' 07"	89° 48' 13"	-2.96	30.18	CPT - Fill Area
MC5-1	29° 44' 02"	89° 48' 57"	-1.86	31.09	CPT - Fill Area
MC5-6-2	29° 43' 46"	89° 49' 01"	-3.06	30.83	CPT - Fill Area
MC5-8	29° 43' 43"	89° 48' 42"	-4.78	30.5	CPT - Fill Area
MC5-11	29° 43' 28"	89° 49' 06"	-1.87	31.36	CPT - Fill Area
T1-1	29° 45' 29"	89° 49' 13"	-3.2	30.5	CPT - Terrace Area
T1-2	29° 45' 15"	89° 48' 44"	-2.19	30.44	CPT - Terrace Area
T1-3-2	29° 45' 26"	89° 48' 56"	-1.91	30.7	CPT - Terrace Area
T2-4	29° 45' 28"	89° 48' 08"	-2.47	30.5	CPT - Terrace Area
T3-1-2	29° 44' 43"	89° 48' 36"	-2.29	30.7	CPT - Terrace Area
T3-2	29° 44' 56"	89° 48' 36"	-1.61	30.5	CPT - Terrace Area
T4-2	29° 44' 32"	89° 48' 37"	-1.88	31.03	CPT - Terrace Area
T4-4	29° 44' 12"	89° 48' 46"	-1.88	30.96	CPT - Terrace Area

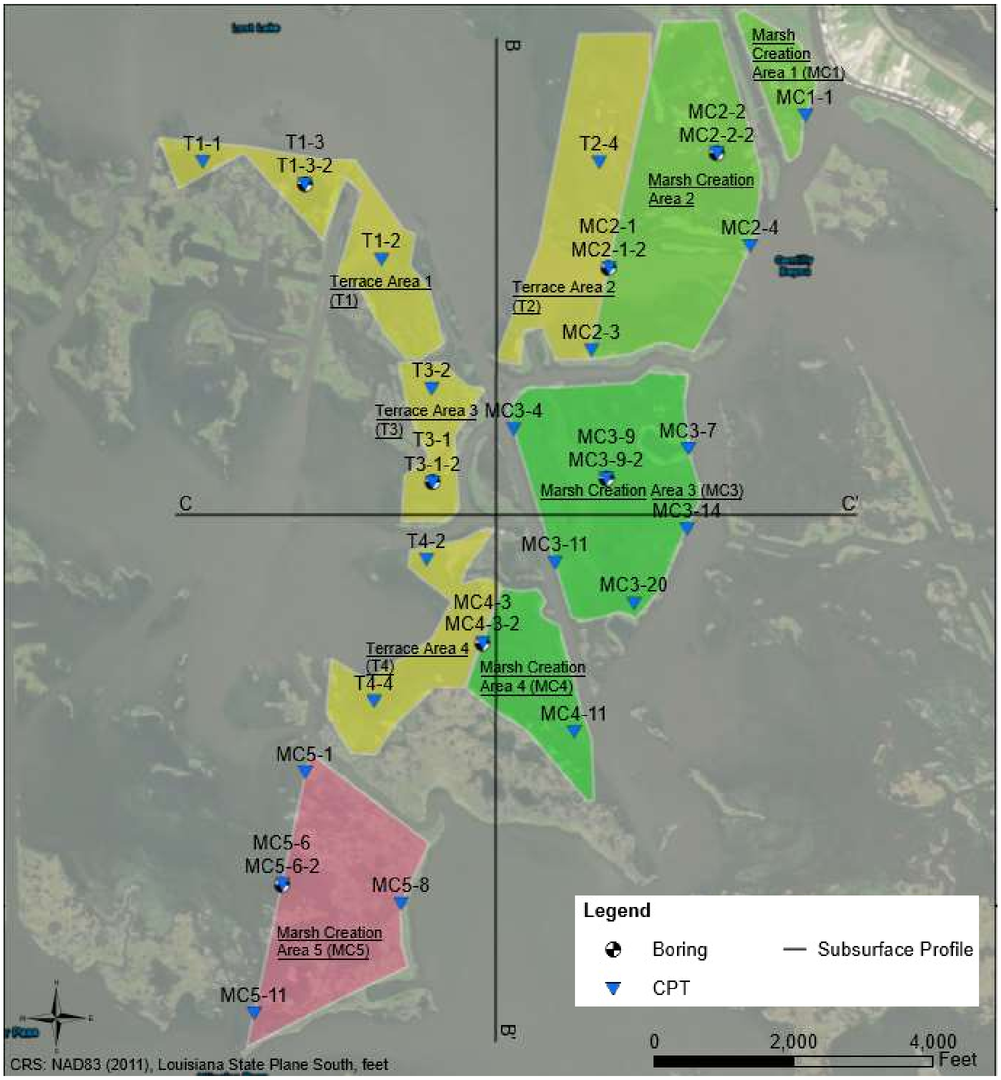

Figure 11: MC Fill/Terrace Area Geotechnical Sampling Locations

4.2.3 Borrow Area Geotechnical Subsurface Investigation

Soil conditions were evaluated in the Lake Lery borrow area by advancing eight (8) borings to twenty (20) feet below the existing mudline. The soil borings were performed in approximately six (6) feet of water using an airboat-mounted drill rig. Index properties observed during drilling and laboratory test results are located on the boring logs in **Appendix E**.

Subsurface soils gathered from the eight (8) borings (**Figure 12**) within the borrow area primarily consist of soft clays and peats to depths of five (5) feet below the surface and milder and stiffer clays from five (5) to fifteen (15) feet below the surface. The proposed fourteen (14)-foot cut depth in the borrow area extends from an elevation of minus-six (-6) feet NAVD88 to minus-twenty (-20) feet NAVD88. The determination for this cut depth is provided in **Section 5.4**.

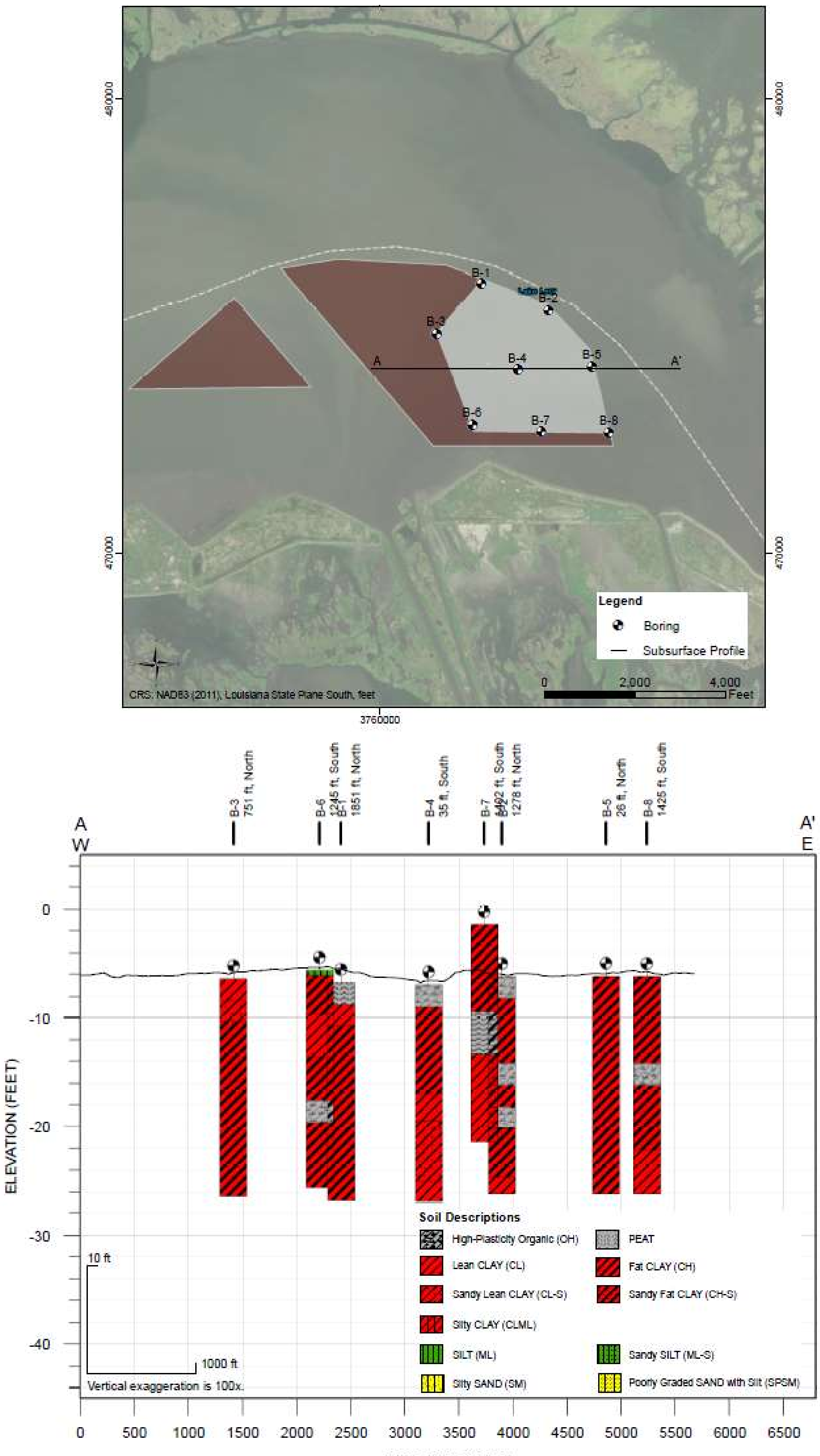

Figure 12: Borrow Area Geotechnical Sampling Locations and Profiles. Brown outline denotes permitted area.

5.0 PROJECT DESIGN

This project proposes to create marsh by hydraulically dredging material from Lake Lery into four separate marsh creation areas (MCAs) with one (1) additive alternate marsh creation area as shown in **Figure 13** and drawings in **Appendix G**. In addition to the MCAs, approximately 22,000 LF of earthen terracing is included to the west of MCA-2, MCA-3, and MCA-4.

5.1 Marsh Creation Area Design

The alignment of the MCAs were modified from the original Phase 0 configuration to the current configuration shown in **Figure 13**. The Phase 0 configuration had four main terrace areas and four main MCAs with containment features traversing multiple open water segments. In Phase 1, a fifth MCA was proposed as an additive alternate to the project, and the boundary of MCA-1 was relocated southward to avoid a cultural area to the north. Based on the surveys conducted on these areas, the ECD alignments and terraces were modified to avoid pipelines and cultural areas. Further information is provided in the Survey Report (**Appendix D**).

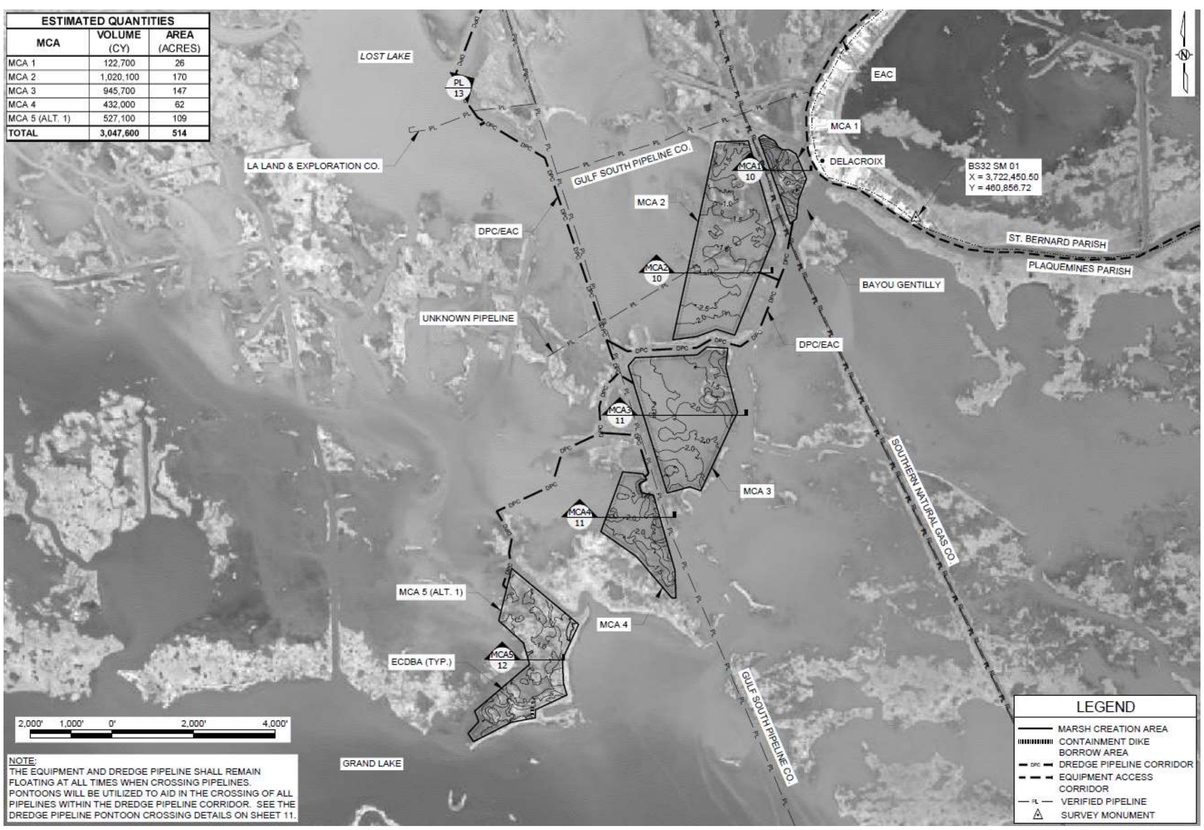

Figure 13: 95% Marsh Creation Design Plan View of BS-0032. Note that MCAs are numbered sequentially from northeast to southwest.

To achieve the project goals, the dredged slurry will need to be placed to a constructed fill elevation above the functional intermediate marsh range and will settle into the range over the 20-year design life. An illustration of the project area mudline contours is shown in **Figure 14** with a corresponding elevations table shown in **Table 5**. In summary, approximately 95% of mudline elevations are between +0.5 and -2.5 feet NAVD88.

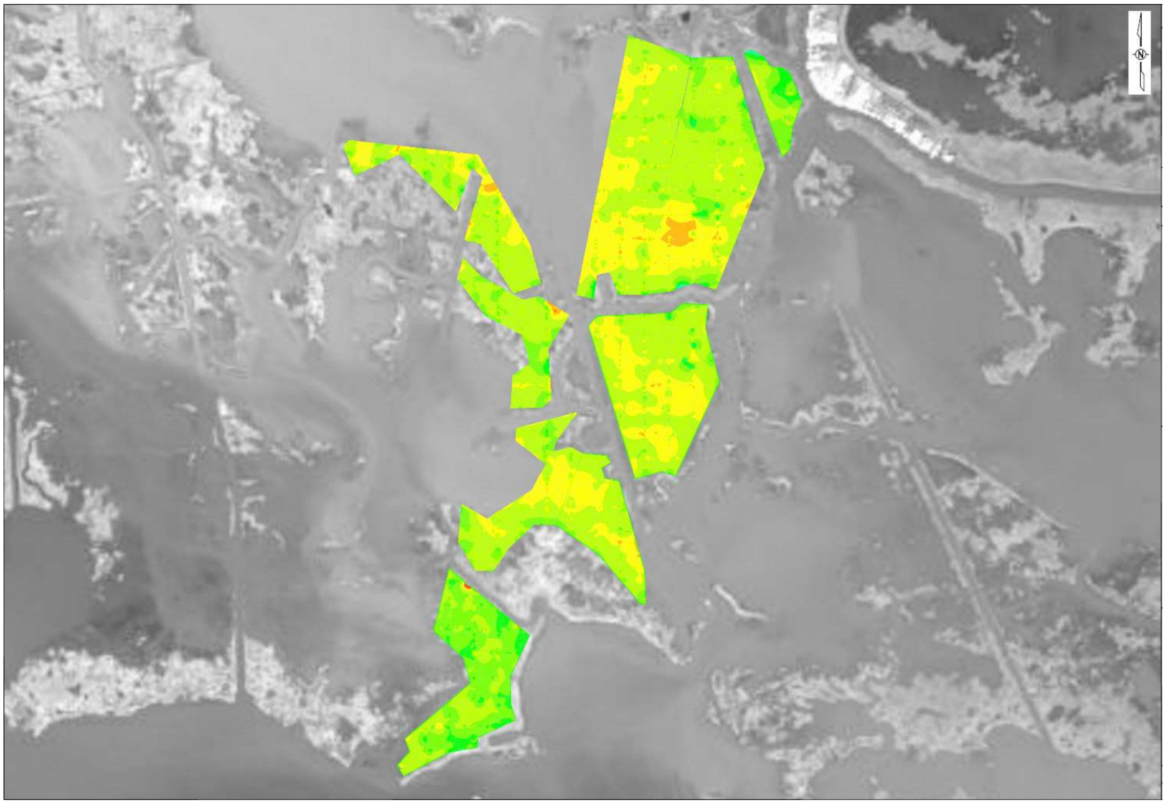

Figure 14: Project Area Mudline Contours. Colors correspond to elevation ranges shown in Table 5.

Table 5: Elevations Table

Elevations Table			
Number	Minimum Elevation	Maximum Elevation	Color
1	-18.00	-6.00	
2	-6.00	-5.00	
3	-5.00	-4.00	
4	-4.00	-3.00	
5	-3.00	-2.00	
6	-2.00	-1.00	
7	-1.00	0.00	
8	0.00	1.00	
9	1.00	2.00	
10	2.00	3.00	
11	3.00	4.00	
12	4.00	5.00	

5.1.1 MCA-1

MCA-1 is a favorable candidate to help protect the community of Delacroix since it is the closest MCA to Delacroix Island. Dredged material will be placed near the existing marsh to increase the elevation in order to meet the necessary elevation required for the ECD. According to design analysis, 122,700 cubic yards of slurry will need to be pumped into this twenty-six (26)-acre fill area. As previously mentioned in **Section 5.1**, a cultural area has been identified north of MCA-1, and a buffer of fifty (50) meters from the ECD is included to protect cultural resources. This required a reduction of the MCA by 0.5 acres. The average mudline elevation for MCA-1 is -0.70 ft. NAVD88 as shown in **Appendix D**.

5.1.2 MCA-2

MCA-2 consists of a substantial amount of open water with a few marsh areas that will be used as a template to construct a boundary of ECD. The cell is bisected by an 8-inch field line with a depth of cover between two and a half (2.5) to five (5) feet. This pipeline was plugged and abandoned in the late 1990's, and current ownership is unclear. The 95% design includes constructing ECD and placing dredged fill material over the existing pipeline. Correspondence with multiple pipeline owners in the vicinity confirm that the line is no longer active. Prior to construction, a notice will be sent to all potential owners. According to design analysis, 1,020,100 cubic yards of slurry will need to be pumped into this one-hundred seventy (170)-acre fill area. The average mudline elevation for MCA-2 is -1.64 ft. NAVD88 as shown in **Appendix D**.

5.1.3 MCA-3

MCA-3 consists of a substantial amount of open water with few marsh areas that will be used as a template to construct a boundary of ECD. According to design analysis, 945,700 cubic yards of slurry will need to be pumped into this one hundred forty-seven (147)-acre fill area. The average mudline elevation for MCA-3 is -1.84 ft. NAVD88 as shown in **Appendix D**.

5.1.4 MCA-4

MCA-4 consists of a substantial amount of open water with some marsh areas in the southern area of the cell, which will be used as a template to construct a boundary of ECD. According to design analysis, 432,000 cubic yards of slurry will need to be pumped into this sixty-two (62)-acre fill area. The average mudline elevation for MCA-4 is -1.85 ft. NAVD88 as shown in **Appendix D**.

5.1.5 MCA-5 (Additive Alternate)

MCA-5 is an additive alternate area for the BS-0032 project, which was added to provide additional acres of marsh creation using the designated borrow area. This area was selected as an alternate because it is the next adjacent cell in the East Bank Land Bridge as outlined in the 2017 Master Plan. According to design analysis, 527,100 cubic yards of slurry will need to be pumped into this one hundred nine (109)-acre fill area. The average mudline elevation within MCA-5 is -0.90 ft. NAVD88 as shown in **Appendix D**.

5.2 Marsh Creation Area Settlement Analysis

Marsh fill settlement analysis is necessary to determine the construction fill elevation of the marsh creation areas and the total volume of fill material. The final elevation of the marsh creation area (at 20-year project life) is governed by two forms of settlement: (1) the settlement of the underlying soils in the marsh creation areas caused by the loading exerted by the placement of dredged fill material, and (2) the self-weight consolidation of the dredged material. Data from column settling tests and low-pressure consolidation tests were used to estimate the magnitude and time-rate of settlement of the slurry, and data from traditional consolidation testing were used to determine the settlement of the underlying soils of the marsh creation areas.

To understand the settling processes and properties of the dredged slurry, a column settling test was performed by Fugro using the test method specified in the United States Army Corps of Engineers (USACE) Engineering Manual No. 1110-2-5027. Additionally, low-stress consolidation tests were performed to analyze the self-weight consolidation of the dredged material (EM 1110-2-5027) after sedimentation. The column settling tests provide an insight into the sedimentation behavior of the marsh fill when placed within the marsh creation area, while low-stress consolidation tests are used to measure the consolidation properties of the dredged material under increasing low-magnitude loading conditions. Together, the results of these tests are used to determine an initial void ratio of the dredged material, *e0*, taken as the point when the slurry changes from zone settling to compression settling. The initial void ratio and the consolidation properties determined in these tests are used to estimate the magnitude and time-rate settlement of the dredged material using the Primary Consolidation, Secondary Compression, and Desiccation of Dredged Fill (PSDDF) program developed by Dr. Timothy D. Stark. Settlement of the subgrade materials was estimated by Fugro using PSDDF.

One pilot-scale settling column test was performed as per the MCDG 1.0, Appendix B, Section 2.7.4 (USACE EM 1110-2-5027). This test was conducted to determine settlement curves that display zone settling and compression settling components. The test was conducted using a composite sample containing the fine-grained fraction of sediments from five (5) of the Lake Lery borings (B-1, B-2, B-3, B-4, B-6) to a depth of twelve (12) feet. For the pilot-scale settling column test, the composite sample was mixed to an initial concentration of 300 g/L. Results from the BS-0032 pilot-scale settling test are shown in **Figure 15**. This test was performed to gather necessary data for PSDDF inputs.

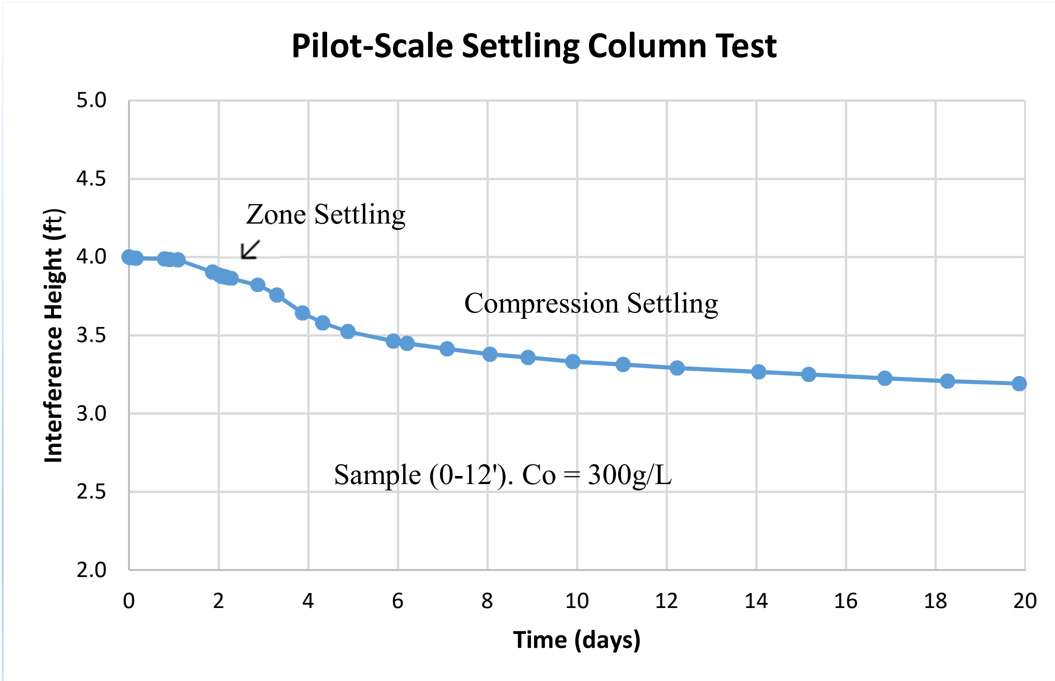

Figure 15: Zone and compression settling results from the column-settling test

Inspection of the pilot-scale settling curve depicted in **Figure 15** shows that compression settling occurred after 104 hours. At this time, transition from zone settling to compression settling begins, and after four days, the pilot-scale settling test shows that the interface height has reached 3.2 ft. or 80% of the initial height of 4.0 ft.

5.2.1 Construction Marsh Fill Elevation

The next step in the settlement analysis involved determining an appropriate constructed marsh fill elevation (CMFE) as per MCDG1.0 Section 3.6.2. This elevation is governed by several factors including tidal range, percent inundation, average existing marsh elevations, physical properties of the borrow material, and the bearing capacity of the foundation soils in the MCA. The CMFE was selected to maximize the time that the marsh platform elevation is within the functional intermediate marsh inundation range (10%-90% inundated). Over the 20-year project design life, as discussed in **Section 3.3**, the preferred inundation range is expected to rise from -0.11 ft. NAVD88 to 0.39 ft. NAVD88 (90% inundated), and from 1.52 ft. NAVD88 to 2.02 ft. NAVD88 (10% inundated).

To determine the CMFE that would yield the most productive marsh within the 20-year project life, water levels in the project area, eustatic sea-level rise (ESLR), and subsidence rates for the project area were analyzed.

Subsidence rates were applied to the marsh fill elevation (settlement curves), while ESLR was applied to the tidal datum and the optimal inundation range. The ideal final marsh platform would settle into the optimal intermediate marsh range (10%-90% inundated) shortly after construction and would remain there for the duration of the 20-year project life. Fugro provided construction marsh fill settlement recommendations for the marsh creation area that would maximize the amount of time that the marsh platform would remain within the 10% to 90% inundation range. Fugro modeled construction of MCAs with final marsh construction fill elevations equal to +2.8 feet NAVD88 for MCA-1 and MCA-5 and +3.5 feet NAVD88 for MCA-2, MCA-3, and MCA-4, as shown in **Figure 16.**

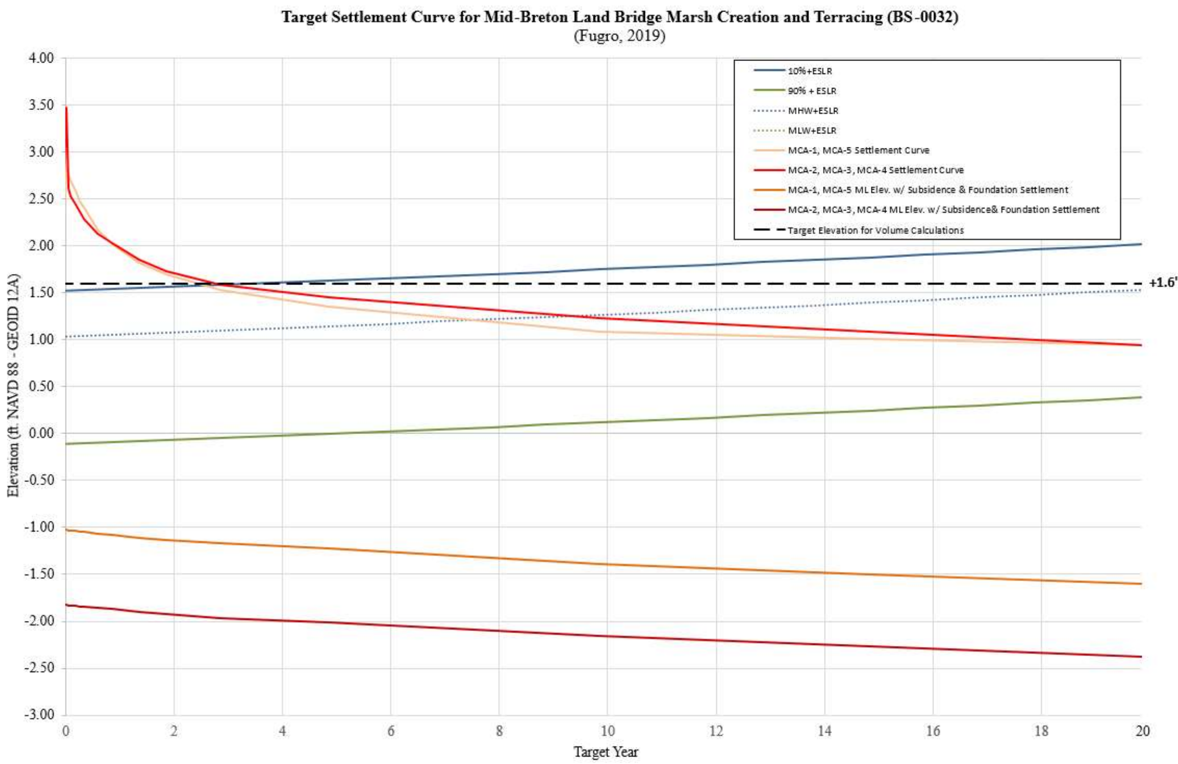

Figure 16: Estimated Total Settlement Curves with 10% and 90% inundation (intermediate) MHW+ ESLR & MLW + ESLR, including subsidence, and mudline settlement.

The +2.8-foot CMFE for MCA-1 and MCA-5 and +3.5-foot CMFE for MCA-2, MCA-3, and MCA-4 falls within the target inundation range within three (3) years after construction and remains within the inundation range beyond the 20-year project design life.

5.2.2 Accretion Investigation

CPRA's Lafayette Regional Office performed a study of observed accretion and elevation change rates at monitoring sites in marsh creation areas. Results suggest that surface elevation of created marsh can keep up with subsidence rates, and in many instances, accretion rates result in an increase in vertical surface elevation (Sharp and Mouledous 2019).

Created marsh surfaces will begin to gain elevation once the marsh platform falls within the target inundation range and vegetation becomes established. Accretion can be applied once the marsh fill platform falls within the 10% inundation range. Based on the +2.8 ft.

and +3.5 ft. NAVD88 CMFE settlement curves shown in **Figure 16,** this occurs three (3) years after construction.

Based on conclusions in this study, an observed accretion rate of 0.3 cm/year is expected at TY3. The cumulative elevation gain from accretion over seventeen (17) years amounts to an increase of roughly 2.0 inches (0.17 feet).

To remain conservative, this project design will not take into account the elevation gain from accretion when calculating quantities.

5.2.3 Constructed Marsh Creation Area Quantities

After determining the constructed marsh fill elevations, the total volume of the marsh creation area was calculated using AutoCAD Civil software. The software creates a 3-dimensional surface based on three-dimensional coordinate data from survey data. This surface is known as the triangulated irregular network (TIN). The TIN model represents a surface as a set of contiguous, non-overlapping triangles. TINs from the 2019 survey data and a flat TIN surface at the 20-year target elevation were created using AutoCAD. The XYZ differences between each surface were then used to calculate the volume of the marsh creation area. Since the internal containment borrow must be refilled, the volume to build the containment dikes, including a cut-to-fill ratio of 1.5 for the dikes, was then added to the volume required to fill each of the marsh creation areas. Finally, the cut-to-fill ratio of 1.1 for fill is applied, resulting in a final estimate of volumes for the marsh creation areas. The determination of the cut-to-fill ratio is explained in **Section 5.6**. **Table 6** summarizes the fill volumes for the BS-0032 project.

Table 6: Summary MCA Acreages and Volumes (includes ECD Borrow Volume)

Fill Area	Fill Elevation (ft. NAVD88)	Area (Acres)	Cut to Fill Ratio	Volume of Cut/Fill (yd^3)
1	+2.8	26	1.1:1	122,700
2	+3.5	170	1.1:1	1,020,100
3	+3.5	147	1.1:1	945,700
4	+3.5	62	1.1:1	432,000
5 (Add. Alt.)	+2.8	109	1.1:1	527,100
TOTAL w/o Add. Alt.		**405**		**2,520,500**
TOTAL w/ Add. Alt.		**514**		**3,047,600**

Though the final constructed fill elevation of the marsh creation areas will be +2.8 ft. and +3.5 ft., NAVD88, volume calculations were determined near the ultimate settled CMFE to allow for primary and secondary consolidation settlement of the fill to occur. This process accounts for the decrease in voids, primarily water, as the material dewaters and begins to consolidate. As shown in the settlement curve in **Figure 16**, the fill elevation decreases at a much quicker rate within the first few years after construction as compared to the mid-to-later years due to the draining of excess pore water. Near the completion of primary consolidation settlement, the material has dewatered giving a more accurate estimate of the actual volume of dredged material needed to achieve the target marsh elevation. The target elevation used to calculate volumes does not include the elevation gain from accretion.

5.3 Earthen Containment Dike Design

The primary design parameters associated with the ECD design include the crown elevation, crown width, and side slopes. The crown elevation is determined from an assumed initial fill elevation within the MCA. Several factors drive the initial fill elevation and thus the design elevation of containment dikes on marsh creation projects. These factors include the dredge production rate, the specific gravity of the slurry, and the volume of solids required to achieve the target 20-year elevation. The dredge production rate and the solids concentration will vary depending on which dredge mobilizes to the project and how the contractor intends to operate. Mobilization of an eighteen (18)-inch cutter-head dredge is expected for construction of this project due to the borrow area environment. Typically, eighteen (18)-inch cutter-head dredges will operate between five hundred (500) to five thousand (5,000) cubic yards per hour and with a slurry specific gravity between 1.10-1.40. Dredge production parameters used to determine the containment height required to contain the total volume of solids and water inside the average marsh creation cell for this project are shown in **Table 7**.

Table 7: Dredge Production Parameters

Borrow Area	18" Dredge			
S.G.	Pipe Diameter	Average Velocity	Slurry S.G.	Average Solids Production
	in.	ft/sec	(1.1 - 1.4)	CY/hour
2.64	18	17	1.30	1,092

The specific gravity or slurry concentration throughout the fill area will vary during dredging. A specific gravity of 1.30 represents the average specific gravity of slurry throughout the marsh creation area during placement. This calculation, further detailed in **Appendix H**, can provide a good approximation of the volume occupied by the solids and water inside the average marsh creation cell during dredging and thus the required containment dike height. The crown elevation of containment dike required at this dredge slurry concentration is +5.0 feet (NAVD88) as shown in **Appendix H**.

Due to the variability in size and acreage of the five (5) different MCAs of this project, it will be recommended that the contractor fill a minimum of two (2) marsh creation areas simultaneously using wye valves. This will reduce the dredge production rate within each cell and allow more residence time for the material to decant and consolidate. This will reduce the height of the slurry thickness within each cell, increase the storage volume of solids within the MCA over time and significantly reduce the risk of losses from overtopping and dewatering.

Degradation of the ECDs will be performed after construction and before demobilization and is estimated to be half of the total LF of the ECDs. The ECDs that will not be degraded will be adjacent to the terrace fields and large open water areas. After construction is completed, further ECD degradation will be conducted at year 3.

5.3.1 Earthen Containment Dike Stability

Slope stability analyses using SLOPE/W was performed on the proposed ECDs at different elevations and geometries. Stability analyses were modeled using Spencer's method.

The slope stability of the ECD has two types of driving forces: (1) the forces induced by the soil weight, and (2) any seepage forces, which tend to cause the soil to slide. In response to these driving forces, the subsurface soils have a resistant force in the form of shear strength, which attempts to keep the slope from sliding. Both the driving forces and the resisting forces are dependent on the geometry and soil parameters of the proposed features. Fugro performed stability analyses that compute factors of safety against potential failure based on limit equilibrium theory.

In the slope stability analyses, tension cracks were also evaluated. Tension forces within cohesive soils may be observed in the upper part of the slope. A tension crack may develop in a slope when the inclination angle of the slip surface is steep and when the sliding mass is sitting on a weak foundation material. This can be modeled in SLOPE/W by creating a tension crack boundary. The tension crack boundary was created with a water-filled tension crack line to a depth of one (1) foot below the crown of the ECD.

Stability runs included evaluating:

1) Internal failure of ECD with tension crack, no marsh placed.
2) Internal failure of ECD with tension crack, marsh fill placed.
3) Global failure of ECD into borrow channel.
4) Global failure of ECD into borrow channel, with equipment load.
   (Vertical load surcharge = 260 PCF).

ECD side slopes of 4H:1V were determined to meet the minimum factor of safety for stability. CPRA also evaluated stability for ECDs with side slopes of 4H:1V using the Slope/W input files generated by Fugro. These files contain the material properties of the subsurface soil such as unit weight and the undrained shear strength profile generated by Fugro. The unit weight and undrained shear strength profiles used for all slope stability evaluations are shown on Plate B-4 and B-5 of the Geotechnical Engineering Report (GER) in **Appendix F**.

A minimum slope stability factor of safety of 1.20 is required as per the *MCDG1.0, Geotechnical Standards Table B-8*. A summary of the results for the slope stability analysis is shown in **Table 8**.

Table 8: ECD Slope Stability Results

Condition	**Mudline Elevation** (ft. NAVD88)	**Crest Elevation** (ft. NAVD88)	**Borrow Excavation Offset** (ft.)	**Berm Side Slope**	**Minimum Factor of Safety** (1.2)
ECD No Fill (MC3, MC4, T1 West, T4 East)	-2.3	+5.0	25	4H:1V	1.25
ECD +4.0' Fill (MC3, MC4)	-2.3	+5.0	25	4H:1V	1.28
ECD No Fill (MC1, MC2, MC5, T1 East, T2, T3)	-2.3	+5.0	25	4H: 1V	1.35
ECD +4.0 Fill (MC1, MC2, MC5, T1 East, T2, T3)	-2.3	+5.0	25	4H: 1V	1.28
ECD No Fill (MC1, MC2, MC5)	-1.0	+5.0	25	4H:1V	1.34
ECD +4.0 Fill (MC1, MC2, MC5)	-1.0	+5.0	25	4H:1V	1.21

Results indicate that the majority of the project area could be contained successfully with a +5.0-crest dike elevation and side slopes of 4H:1V. The design elevation of the ECDs (+5.0 ft. NAVD88) is discussed in **Section 5.3**.

A typical geometry and elevation are shown in **Figure 17**. A summary of the ECD quantities is shown in **Table 9**.

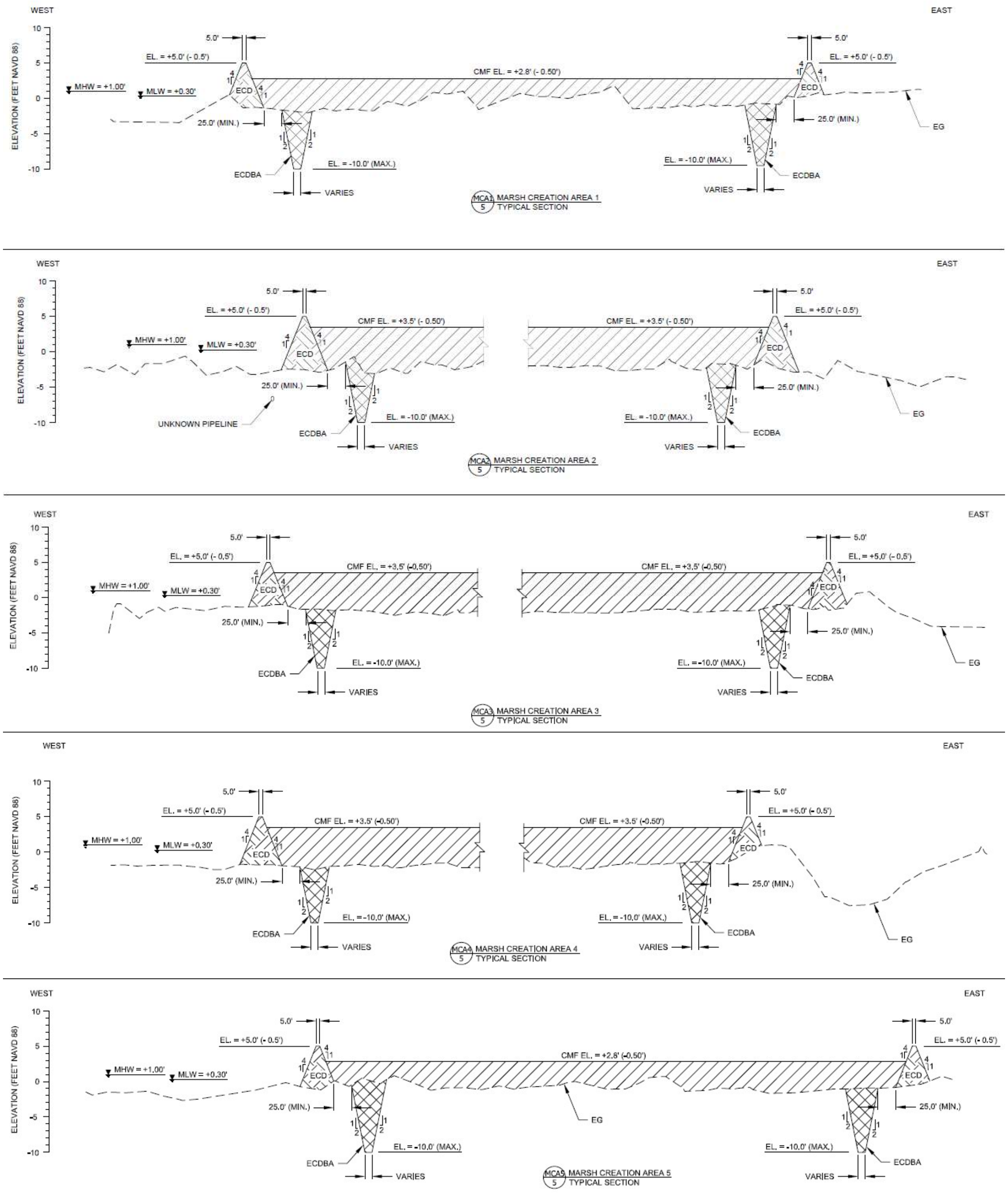

Figure 17: Typical Marsh Fill and ECD Section

Table 9: Summary of ECD Design and Quantities

Marsh Creation Area	CL linear ft	Volume of Fill (cy)	Cut to Fill	Volume of Cut (cy)				
ECD 1	5,232	17,717	1.5:1	26,575		*5.0' top el; 5' top width; 4:1 slope*		
ECD 2	12,400	88,344	1.5:1	132,515		*5.0' top el; 5' top width; 4:1 slope*		
ECD 3	10,489	82,837	1.5:1	124,256		*5.0' top el; 5' top width; 4:1 slope*		
ECD 4	8,054	61,724	1.5:1	92,585		*5.0' top el; 5' top width; 4:1 slope*		
ECD 5 (additive)	12,022	76,768	1.5:1	115,152		*5.0' top el; 5' top width; 4:1 slope*		
Total	***48,197***	*327,389*		**491,083**				

5.3.2 Earthen Dike Settlement

Consolidation settlement of the foundation soils beneath the +5.0 feet (NAVD88) ECDs were computed based on the dike geometries determined from the slope stability analyses and the soil properties of the underlying soils. Total settlement factors include regional subsidence and elastic settlement of the in-situ soils. The total settlement (including subsidence) of the mudline beneath the ECD centerline is 1.0 ft. over the 20-year design life. Figures of the ECD settlement results can be found on Plates C-26 through C-39 of the GER in **Appendix F**.

5.3.3 Terracing Area Design

The alignment of the terracing area was modified from the original Phase 0 configuration to the current configuration shown in **Figure 18**. The Phase 0 configuration was modified to avoid known pipelines, the dredge pipeline corridor and orient the terraces to be perpendicular to the lakes. Each of the terraces will be constructed to an elevation of +3 feet with a centerline to centerline distance of two hundred fifty (250) feet. Each terrace will be approximately 500 feet in length with a total terracing length of approximately 22,000 LF.

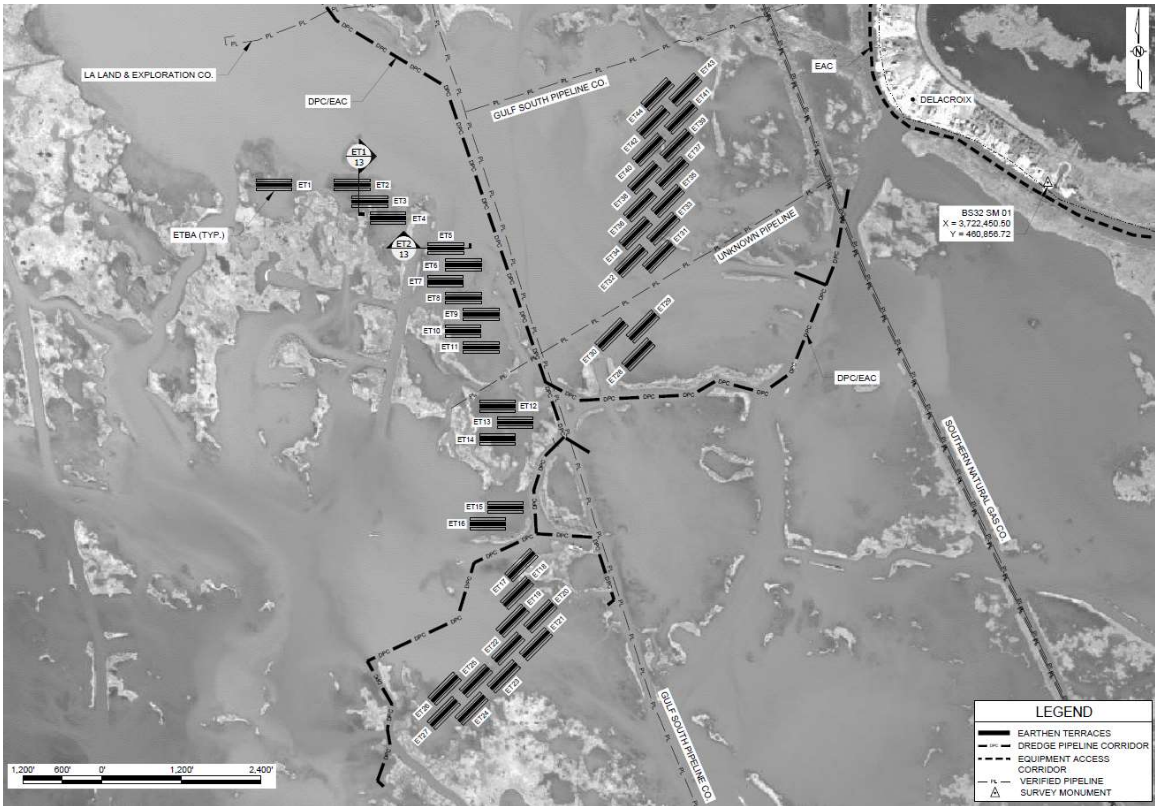

Figure 18: 95% Terracing Design Plan View of BS-0032

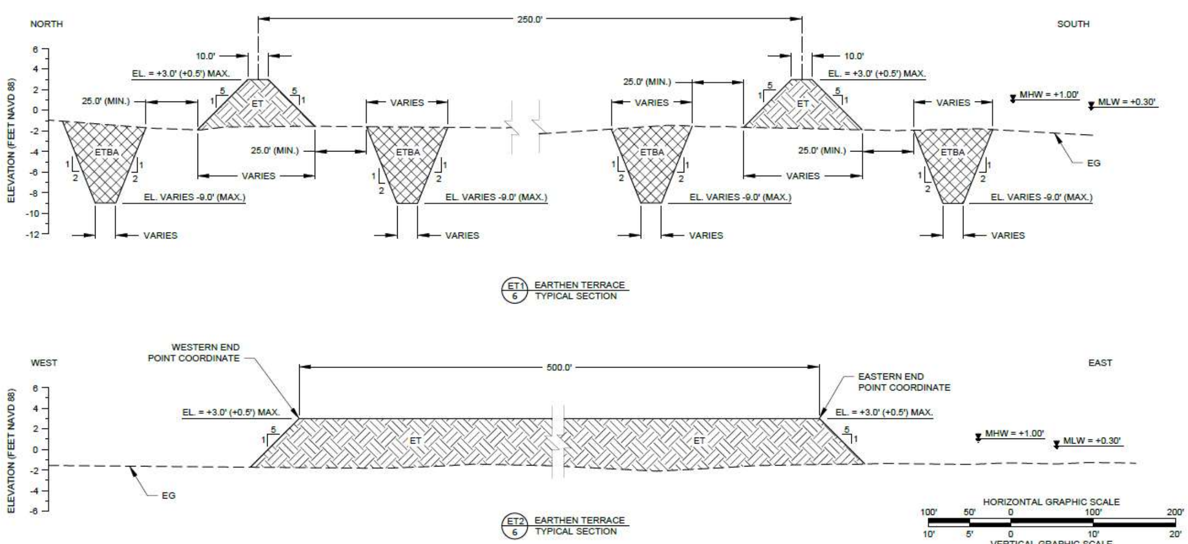

Figure 19: Typical Terrace Section

5.4 Marsh Creation Borrow Area Design

The proposed borrow area is located in Lake Lery, 2.5 miles northwest of Delacroix Island and 4.5 miles north of the MCAs. The borrow cut area is approximately 145 acres and the location, bathymetry, and magnetometer anomalies are shown in **Appendix D**, while the boring sample locations of the borrow area are shown in **Figure 12** and in **Appendix F**.

The typical controlling factors in the marsh creation borrow area (MCBA) design are the location, quantity, and suitability of material. It is preferred that the borrow area be located near the marsh creation area to minimize the pumping distance of the dredged material and thus minimize the dredging cost. The borrow area should be free of any existing oyster leases, critical habitat, culturally significant sites, and infrastructure, if possible.

The available volume of material within the cut borrow area can be found in **Table 10**.

Table 10: Proposed MCBA Acreages and Volumes

Borrow Area	Area (Acres)	Cut Depth (ft.)	Available Volume (CY)
Total	145	14	3,336,000

The density, moisture content, and void ratios of the borrow area soils are summarized in **Figure 20**.

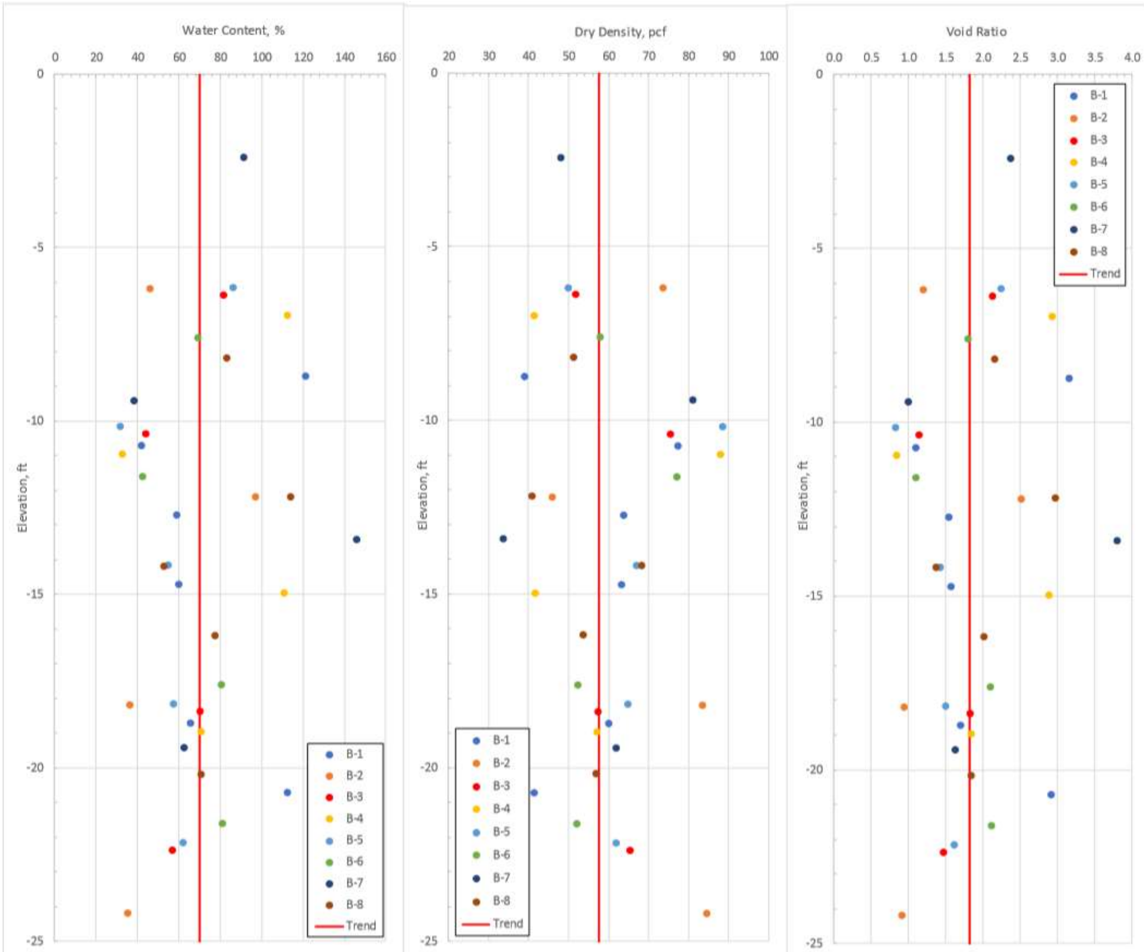

Figure 20: Lake Lery Borrow Area Borings, Moisture Content, Void Ratio, and Dry Density vs Elevation (Fugro 2019)

The geotechnical behavior of clay material during the dredging process is particularly important for estimating the difficulty of transporting sediment. Dredging cohesive soils and hydraulically transporting them via pipeline can be an inefficient process depending on the material's geotechnical properties. The top fourteen (14) feet of the Lake Lery borrow area trends to a material consisting of soft clays with low unit weight and high water content. Borings B-5, B-7, and B-8 are the only boring samples that contained substantial amounts of fat clay for the top fourteen (14) feet below the mudline (**Appendix F**). This area of the borrow area will be avoided to ensure the borrow area is a mixture of peat, lean clay, organic clay, and fat clay. The mixture amounts within the top fourteen (14) feet will lower the risk of clay-balling within the dredge pipeline and will be relatively easier-to-dredge material. Below the fourteen (14)-foot cut depth, the material consists of heavier stiff clay that would require more energy to cut and convey.

5.5 Cut-to-Fill Ratios

5.5.1 Containment Dike

For this project, a cut-to-fill ratio of 1.5 will be used for mechanical dredging of the ECDs to account for contingency/losses and is accounted for in the marsh fill volume.

5.5.2 Marsh Fill

The cut-to-fill ratio for marsh fill was estimated 20 years after dredging using the following equation from EM1110-2-5025:

$$V_f = V_i\left\{\left(\frac{e_o - e_i}{1 + e_i}\right) + 1\right\}$$

Where,

V_f = volume of fine-grained dredged material after placement, yd^3
V_i = volume of fine-grained sediments from borrow area, yd^3
e_i = average in-situ void ratio of the borrow area
e_o = void ratio after 20 years.

Based on bore sampling in the borrow area, the volume of "fine-grained" or clay sediment from the proposed cut area is nearly 100%. The initial in-situ void ratio in the top fifteen (15) feet of the borrow area is 1.8. At 20 years, the void ratio throughout the fill area water column will increase in height and get closer to the initial void ratio taken from the borrow area. Based on the PSDDF output data, the average void ratio in the fill area at 20 years is 1.92. The calculated cut-to-fill ratio using the equation shown above is 1.0. A 10% additional volume was added to this to account for losses to yield a 1.1:1 cut-to-fill ratio.

5.6 Wave Modeling Decision

One area that is frequently of concern with marsh creation projects is the possibility of impacting wave dynamics and increasing shoreline erosion due to bathymetry changes from the dredging of the borrow areas. Following recommendations set forth by the CPRA Technical Memorandum, TM-D-MC-09-01, numerical wave modelling for the Mid-Breton Land Bridge Marsh Creation and Terracing project was deemed unnecessary at this time due to lack of justification for extreme or unusual circumstances.

5.7 Dredge Pipeline Corridor Alignment Design

The dredge pipeline will float over existing pipelines in the area. For the base project, the pipeline corridor from the Lake Lery borrow area to the furthest marsh creation fill area (MCA-4) is 4.7 miles long (yellow). Wye valves will be positioned at strategic locations to fill the remaining cells at an average of 4.7 miles (from the BA to MCA-1, MCA-2, and MCA-3). This will increase the residence time of slurry within the MCAs and reduce the risk of overtopping and losses. The additive alternate cell (MCA-5) will have a pumping distance of 5.34 miles from the BA to this fill area. An illustration of the pipeline alignment is shown in **Figure 21**.

Figure 21: Pipeline Corridor Alignment

5.8 Existing Infrastructure

Several transects were surveyed to investigate any potential pipelines or other areas of concern (**Appendix D**). One pipeline was discovered crossing MCA-2 from a Pre-Construction Survey for BS-0032. This pipeline last belonged to the Southern Natural Gas Co. The proposed dredge pipeline corridor alignments and pipelines within the marsh fill and terrace areas are shown in the plans in **Appendix G**. The dredge pipeline will float over the Gulf Coast pipeline, the Southern Natural Gas pipeline, and the LA Land and Exploration pipeline in order to fill the designated MCAs.

6.0 CONSTRUCTION

6.1 Duration

An approximate construction duration was developed assuming an eighteen (18)-inch hydraulic cutter-head dredge. Incorporating weather days, the total construction duration is approximately 554 days for the base project and 62 days for the additive alternate project. Therefore, the total number of construction duration days for the base and additive alternate together is 616 days.

6.2 Cost Estimate

An Engineer's Estimate of Probable Construction Cost was prepared for this project using recent project bid data, and the guidance provided in MCDG1.0 – **Appendix E**. The estimated construction cost is available as a government cost estimate retained by US Fish and Wildlife Services.

6.3 Risk

Engineering Design Documents, Plans and Specifications were prepared by or under the direct supervision of a licensed professional engineer and registered in the state of Louisiana following professional engineering standards as per La. R.S. Title 37, and Louisiana Administrative Code Title 46, Part LXI, Professional and Occupational Standards, as governed by the Louisiana Professional Engineering and Land Surveying Board. The engineering analyses effort completed for this 95% design report provides guidance and insight pertaining to the construction of the proposed project features based on the data acquired to date and shall not be used for bidding. These documents are not to be used for construction, bidding, recordation, conveyance, sales, or as the basis for the issuance of a permit.

It is recommended that the contractor should adhere to the most current publication of "Recommended Best Practices Guide for Safe Dredging near Underwater Gas & Hazardous Liquid Pipelines", developed by the Council for Dredging and Marine Construction Safety, www.cdmcs.org.

7.0 SUMMARY OF CHANGES TO PHASE 0 PROJECT

The summary of changes from the Phase 0 project includes the additive alternate MCA-5, a cutback of the MCA-1 for cultural buffer, and modifications to the ECD in MCA-2, MCA-3, and MCA-4.

The MCA-5 is included as an additive alternate to maximize the utilization of material available in the Lake Lery borrow area. This area was added to the project, because it is the next adjacent cell in the East Bank Land Bridge as outlined in the 2017 Master Plan.

For MCA-1, a cultural resource just north of this cell requires a 50-meter buffer of clearance, therefore a trapezoidal shape was removed from the northern edge of MCA-1 to provide sufficient clearance.

For MCA-2, MCA-3, and MCA-4, the ECD shape was modified to avoid deeper areas and to locate containment features in more shallow water. This will increase the overall amount of marsh creation that can be constructed for these cells.

The Phase 0 plan view alignment is shown in **Figure 22** and the 95% Phase 1 plan view is shown in **Figure 23.**

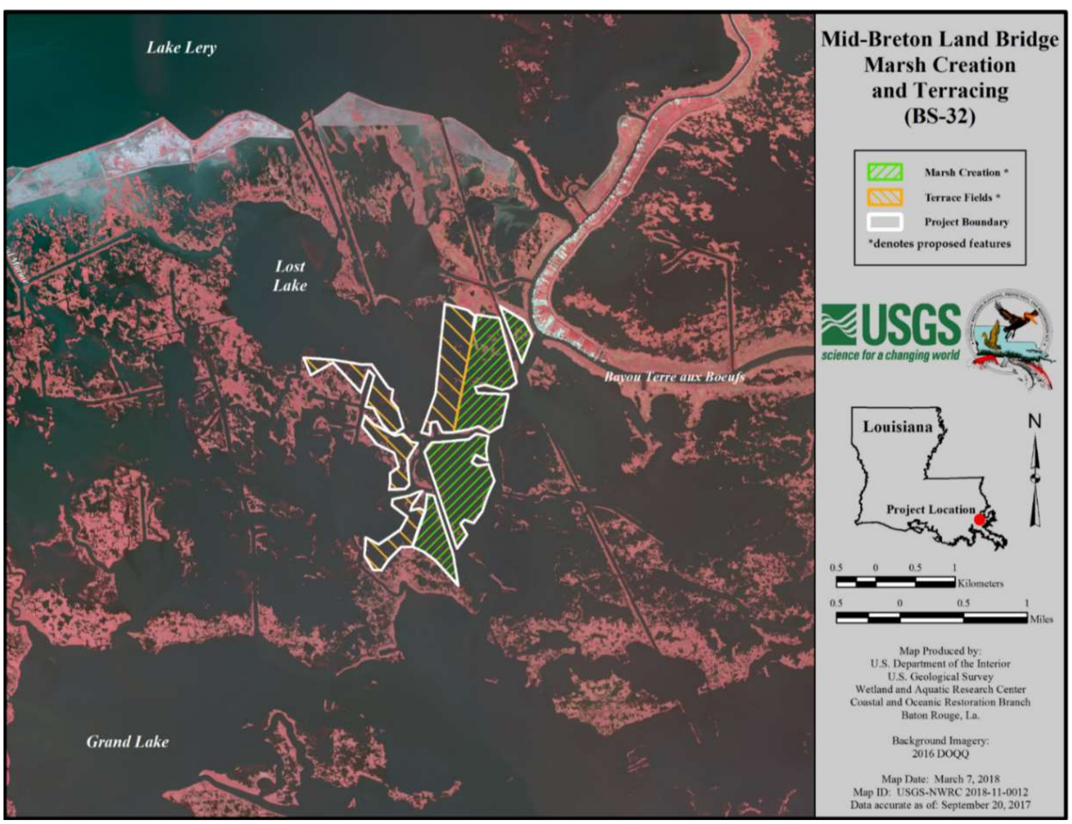

Figure 22: Phase 0 Plan View Alignment

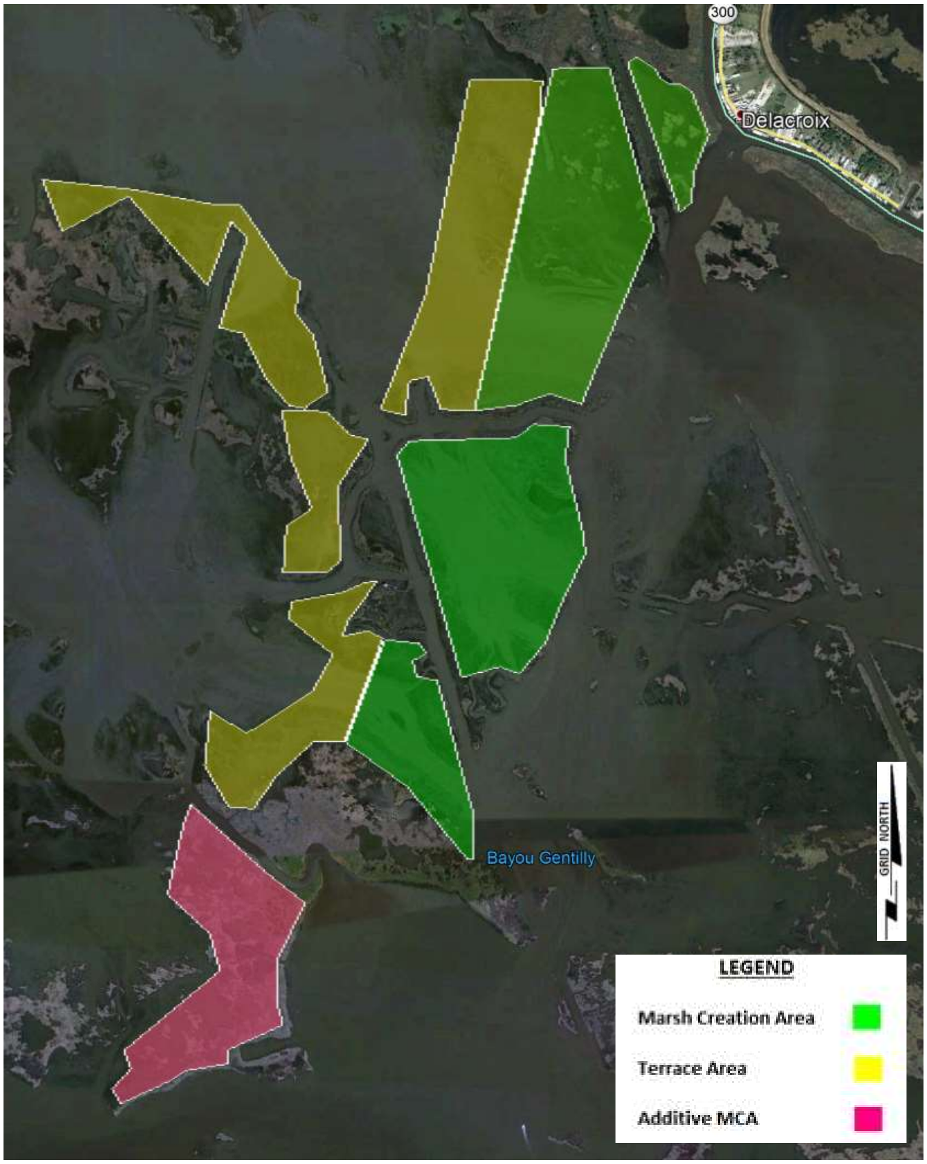

Figure 23: 95% Phase 1 Plan View Alignment

8.0 SUMMARY OF CHANGES FROM 30% DESIGN TO 95% DESIGN

The summary of changes from the 30% design to the 95% design includes the following items:

- Optimized the PSDDF input parameters for the +4.1 feet CMFE for the MCA-2, MCA-3, and MCA-4 settlement curves to yield an updated settlement curve that has a CMFE at +3.5 feet NAVD88 for MCA-2, MCA-3, and MCA-4.
- Evaluated the potential use of a two-lift marsh fill placement methodology. Based on the analysis, it would not be possible to have a two-lift scenario due to the borrow area soil properties, which will remain saturated for a long period of time. Therefore, placing a second lift will re-saturate the borrow material and could cause the re-suspended marsh fill to overtop the earthen containment dikes.
- Optimized the dredge size from 24-inch to 18-inch and dredge pipeline corridor/ equipment access routes.
- Incorporated Histograms into the 95% design package as **Appendix I**.
- Included the breakdown of marsh fill volumes per MCA.
- Assumed an estimated degradation of half of the total LF of ECDs.
- Adjusted the marsh type from brackish marsh to intermediate marsh based off recent WVA.

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Appendices A-J are available from the following link:

ftp://ftp.coastal.la.gov/BS-0032/95_Design